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ELEMENTS

OF

MEDICAL CHEMISTRY.

BY

B. HOWARD RAND, M.D.,

PROFESSOR OF CHEMISTRY IN JEFFERSON MEDICAL COLLEGE.

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PREFACE.

THIS work is intended chiefly for the use of Students of Medicine during their attendance upon lectures; it is believed that it will also be found of service to the practitioner.

The volume may be regarded as a full set of notes of the author's course of lectures in the Jefferson Medical College.

The immense extent of the subjects comprised under the general head of Chemistry and Physics, together with the limited time which the student is able to devote to them, rendered a careful selection of topics necessary. In doing this, it has been the author's aim to discuss thoroughly general principles and their application to medicine, leaving more minute details to be gathered at leisure from the larger text-books. The consideration of purely theoretical points, of disputed facts, or of applications of chemistry not directly connected with medicine, has been, as a general rule, omitted. Chemical affinity, symbols, and nomenclature have been particularly dwelt upon, as they constitute the points of most difficulty to the beginner, while, if they are not clearly understood, no satisfactory progress can be expected. Convinced

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that familiarity with the use of chemical symbols is of the utmost importance, and that it is readily acquired, the author has employed them profusely, preferring in many cases to write the symbol of an element or compound in preference to its name. The older notation, nomenclature, and equivalents have been retained as best adapted for elementary instruction.

Believing in the necessity of a rigid adherence to the U. S. Pharmacopœia, not only as regards the formulæ, but also the titles of preparations, the officinal names have been always used; as often as possible the Latin title has been given, and the formulæ written in prescription style as a useful exercise for the student.

It would have been an easier task to have produced a larger volume; much time and thought have been expended in the selection and condensation of subjects, and it is hoped that the labour thus bestowed will be found to lessen that of the overworked student.

As all the apparatus described is exhibited in operation during the course of lectures, it has not been thought necessary to use many illustrative cuts.

1615 *Summer Street, Philadelphia.*
3d AUGUST, 1866.

TO THE STUDENT.

The numbers in parentheses refer to the paragraph to be consulted.

When the Latin title of a preparation is given, the *officinal* U. S. P. compound is always referred to.

The following are the principal signs and abbreviations used in prescriptions, and also employed in many of the pharmaceutical formulæ in this work.

℞, *Recipe* — Take; ℥, troyounce; f℥, fluidounce; fʒ, fluidrachm; ♏, minim; gtt, *gutta, guttæ,* drop or drops; gr, *granum, grana,* grain or grains; O, *octarius,* a pint; M, *misce,* mix; *ft, fiat,* let there be made; *chart., chartula* or *chartulæ,* a packet or packets; ā̄ā, of each; t. d., *ter die,* thrice daily; q. s., *quantum sufficiat,* as much as is sufficient. The Roman numerals, ss one-half, j one, v five, x ten, l fifty, c one hundred, are usually employed in prescriptions, being placed after the sign. The scruple ℈, drachm ʒ, pound ℔, and gallon, *Cong.,* are not used in the U. S. Pharmacopœia.

A table of weights and measures, American, English, and French; general rules in regard to incompatibles and antidotes; a series of reactions for practice; a list of the more important minerals, and a glossary of terms and synonyms, will be found in the Appendix.

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MEDICAL CHEMISTRY.

INTRODUCTION.

1. **Chemistry** investigates the *reaction* of the *particles* of *matter*. *Reaction* is mutual or reciprocal action, and is due to *force*. Action and reaction are equal and opposite.

In common language we frequently overlook the reaction, and speak of action alone. Thus, vinegar spilled on a polished marble table is said to corrode or damage it, but the vinegar is at the same time neutralised and spoiled for use.

2. **Particles** are the exceedingly minute portions of matter which go to make up a mass. They may be *atoms* (Gr. *a*, not, and *temno*, I cut), which are the ultimate portions of an elementary body; or *molecules* (Lat. *molecula*, a particle), the ultimate portions of a compound body. *Molecules* are composed of two or more atoms.

3. **Matter** is anything that can be grasped in the hand. It may be elementary or compound. All substances known to us are composed of sixty-four bodies, which, having not as yet been decomposed, are termed *elements*. Like the letters of the alphabet, which, variously combined, give us thousands of words, these elements, in various forms and grades of combination, make up the apparently infinite variety of forms of matter

4. **Matter is Indestructible.**—What we term *destruction* is merely a new combination of elements. Solid bodies sometimes become gaseous when burned, and thus, being invisible, are supposed to be destroyed. Experiment shows

this not to be true. When a piece of gun-cotton is burned in a counterpoised exhausted globe, it disappears, but the weight of the globe and its now gaseous contents, is unchanged.

Wood, when burned, gives off carbonic acid and water, which pass into the atmosphere; the water falls to the earth, and may be absorbed by some growing vegetable, to assist in forming again wood. The carbonic acid consists of the elements carbon and oxygen. When absorbed by plants, it is, under certain circumstances, decomposed, the oxygen given out and the carbon assimilated going to form new wood. Hence it would be possible to burn the same combustible twice or more.

5. **Matter is incapable of Spontaneous Change.** — All change is due to force. This property is called *inertia.* The inertia of a body depends upon the number of its particles or its *mass.* Time is required to communicate motion to all these particles, or to abstract it from them; hence all change in matter is gradual.

6. **Weight** is due to the action of gravitation upon a body, and depends also on the mass. The same mass has not always the same weight, as the force of gravitation varies in different localities. Practically, however, the terms may be used as synonymous.

7. **Force** is anything capable of causing change in matter. Of its nature we are utterly ignorant. Although manifesting itself in the various phenomena of gravitation, light, heat, electricity, magnetism, cohesion, adhesion, chemical affinity, and vital force, there can be little doubt that it is in all these essentially the same agent.

8. Force acts to produce either *attraction* or *repulsion.* The particles of matter are not in actual contact; the spaces between them are called *physical pores,* and although exceedingly minute, are believed to be much greater in proportion than the particles themselves.

Newton calculated that if there were no pores, the earth and its inhabitants could be comprised within the space of a cubic inch. What are usually known as pores, as in the sponge, pumice-stone, etc., are not true physical pores, but rather canals or tubes traversing the body; they are distinguished as *sensible* pores.

The force of attraction tends to bring together the particles of matter, and, were there no antagonistic agencies, would do so; the force of repulsion tends to separate these particles. The phenomena of expansion, of contraction, and of change of state are all due to the preponderance of one or the other of these agencies. The great agent of repulsion is heat. We have also electrical and magnetic repulsions. This part of the subject will be more fully considered hereafter.

PART I.

PHYSICS.

GRAVITATION.

9. Is but little connected with Chemistry. The law of gravitation is that every particle of matter attracts every other particle in the direct ratio of its mass, and the inverse ratio of the square of the distance.

10. TERRESTRIAL GRAVITATION—Is the action of the mass of the earth upon bodies on or near its surface. It may be considered as proceeding from its centre (nearly). It is greater at the poles than at the equator, and is less when a body is carried above or below the surface of the earth.

Thus, a mass of iron weighing 1000 lbs. at the equator, would weigh 1005 at the poles; 500 lbs. at 2000 miles below the surface of the earth, or at 1650 miles above it.*

The action of bodies on the earth's surface is reciprocal, and the earth rises to meet a falling body, but the mass of the former is so immense compared with any body which has ever been known to fall through our atmosphere, that the effect is imperceptible.

11. SPECIFIC GRAVITY.—By the term *density* we mean the relation of the mass of a body to its volume, or the number of particles in a given space. By *specific gravity* we mean the relative weights of equal volumes of different bodies, assumed to be at the same temperature and pressure. The term density is often used to express specific gravity.

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* SILLIMAN, *Principles of Physics*, 2d ed., p. 67.

A quart of oxygen, at ordinary pressure and temperature, if forced into the space of a pint, would have its *density* doubled. The *specific gravity* of oxygen—compared with air as unity—is, when taken at a fixed temperature and pressure, 1·106; that is, that if a certain bulk of air weigh 1000 grains, an equal bulk of oxygen will weigh 1106 grains.

In order to compare the weights of equal volumes of different bodies, arbitrary standards are assumed. For solids and liquids, water at 60° F. is chosen as unity; and for gases, air at ordinary atmospheric pressure (30 in. barometer), and 60° F. is assumed as 1000.

Solids and liquids do not perceptibly alter in bulk by ordinary change of atmospheric pressure. All matter varies in bulk by change of temperature, hence the necessity of carefully bringing the bodies to a fixed degree by trial or calculation.

12. **The specific gravity of a solid** is determined on the principle that a body immersed in a liquid, displaces a volume equal to its own. Hence by a known hydrostatic law the immersed body loses weight equal to that of an equal bulk of the liquid. In practice, a solid is first weighed in air, and then in water, and the loss noted. The weight in air divided by the loss of weight in water gives the specific gravity. Or the solid may be put into a vessel with a spout and brimful of water. The quantity which runs out is weighed, and the weight of the body divided by it.

Thus, a piece of iron weighed in air 460 grains, in water 406·16 grains, 460—406·16=58·84 grains; the loss in water, 460÷58·84 =7·8, equal the S. G. of the iron.

13. **When the solid is soluble in water,** its specific gravity is taken in reference to some other liquid. The quantity thus obtained, multiplied by the S. G. of the liquid, gives the S. G. of the solid.

Thus, a piece of sugar weighed in air 400 grains, it lost in oil of turpentine 217·5 grains, 400÷217·5=1·84. The S. G. of the turpentine is ·87, 1·84 × ·87=1·6, equal the S. G. of the sugar.

14. **When the solid is lighter than water,** it is weighed and attached to a body (the weight of which in air and

water is known) sufficient to sink it. This compound mass or *system* is weighed in air, and its loss in water determined. The loss of the heavy body being known, that of the light body is easily determined by subtraction, and the S. G. obtained as before.

Thus, a piece of wood weighed in air 200 grains; attached to a bit of copper the system weighed 2247 grains in air, and 1620 grains in water, losing 627 grains. The copper alone loses in water 230 grains, $627-230=397$, equal the loss of the wood alone, $200\div397=\cdot504$, the S. G. of the wood.

15. **When the solid is in powder,** it is introduced into a counterpoised bottle full of water, the weight of the water being known (specific gravity bottle [16]). Were no water displaced, the weight of the bottle would be increased by that of the powder, but as a bulk of water equal to that of the powder overflows, the new weight is less than the sum by the weight of that water; which quantity, divided *into* the weight of the powder, gives the S. G.

Thus, the bottle holds 1000 grains of water; 150 grains of sand being introduced, the total weight, instead of being 1150 grains, is but 1096 grains; hence 54 grains of water have been displaced, $150\div54=2\cdot764$, S. G. of the sand.

16. **The specific gravity of a liquid** may be ascertained by the bottle, the hydrometer, or by displacement. The specific gravity bottle is made to hold 100 or 1000 grains of distilled water, and is furnished with a counterpoise. The weight in grains of the liquid introduced into the counterpoised bottle gives its S. G. A common light flask may be used by noting its weight when empty, when filled with water to a mark made on the neck by a file, and when filled to the same point with the liquid to be tested. The weight of the latter, divided by that of the water, gives its S. G.

17. **Hydrometers** have a graduated stem, counterpoised below so as to make it float upright. As the instrument sinks deeper in a liquid lighter than water, and less in a heavier liquid, it may be graduated to indicate S. G.

Usually several hydrometers are employed for liquids lighter or heavier than water, so as to avoid the inconvenience of a long stem, and to have the divisions of the scale larger. The graduation may be arbitrary, as in Beaumé's; may indicate percentage by weight or volume in a mixture, as in Tralles' or Richter's, for spirits; may test for comparative purity, as in the lactometers; or may be graduated to the true specific gravity, as in urinometers. The instruments for specific gravity made by Dr. Wilson H. Pile, of Philadelphia, leave nothing to be desired in point of convenience and accuracy. Those with Beaumé's scale have also the corresponding S. G. marked upon them. In using a hydrometer, it should never be *dropped* into a liquid, as the weight of that adhering when it rises above the surface will render its indications faulty.

18. **By Displacement.**—Weigh a solid in air, in water, and in the liquid to be tested; note the loss in each case. The loss being the weight of an equal bulk of the two liquids, by dividing the loss in the latter by that in the water, we get the S. G.

Thus, a glass rod loses in water 171 grains, in alcohol 143 grains, $143 \div 171 = \cdot 836 =$ S. G. of the alcohol.

19. **The Specific Gravity of Gases** is determined by admitting the gas into an exhausted counterpoised globe, capable of containing a known weight of air, and comparing the two.

LIGHT.

The subject of light is but little connected with elementary chemistry. A knowledge of its most important laws, however, is indispensable to a correct understanding of the physiology of vision, and an intelligent use of the various optical instruments used by the physician.

20. **Sources and Velocity of Light.**—The sources of light are the sun, fixed stars, incandescence, phosphorescence, and electricity. The velocity of light varies with

the medium, being less as that is more dense. In air it is estimated at 190,000 miles per second.—(FOUCAULT.)

21. **Nature of Light - Theories.** — 1. The **corpuscular** supposes that luminous corpuscles are thrown off from luminous bodies, each particle producing in its flight in the surrounding ether undulations similar to those produced by a stone falling into water. 2. The **undulatory** theory supposes light to consist of vibrations of an ethereal medium of extreme tenuity, without the onward progress of any substance whatever. The latter theory is now generally accepted, but the language of the former is still retained in explaining the simpler phenomena of the reflection and refraction of light.

22. **Definitions.** — A **ray** is a single (imaginary) line of light. A **beam** is a collection of parallel rays, as from the sun. A **pencil** is a collection of divergent or convergent rays, as the light from a candle, or the sun's rays brought to a focus by a burning-glass. **Luminous** bodies are those from which light proceeds. **Transparent** or **diaphanous** permit light to pass through them, so that bodies on the other side are visible. **Translucent** bodies permit a portion of light to pass in an irregular manner, so that bodies on the other side are indistinctly seen; such are porcelain, oiled paper, and horn. **Opaque** bodies cut off the rays of light; when in very thin leaves, they may become translucent. The **intensity** of light is inversely as the square of the distance. Thus, if two lights, one at a distance twice as great as the other, cast equal shadows, then the more distant light is four times as intense as the other. Instruments for measuring the relative intensity of light from different sources are called *photometers*.

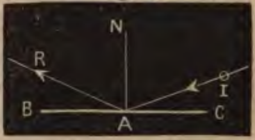
Properties of Light.—A ray of light falling upon a surface may be *reflected*, *transmitted*, or *absorbed*.

23. 1. **Reflection.**—When a surface reflects regularly, it becomes invisible, and an image of an object placed in

front of it is seen; if it reflects irregularly, the surface is visible, and the image is more or less lost. Thus, a bright looking-glass reflects regularly; covered with dust or grease, irregularly. We see bodies then only by this irregular reflection.

(*a*) When a ray of light falls upon a *plane* surface, such as an ordinary mirror, it is reflected at an angle equal to that at which it fell. The law, as ordinarily expressed, is that "the angles of incidence and of reflection are equal, and are in the same plane with the normal.

Fig. 1.



Thus, in the figure, I A and R A form equal angles with N A, the normal or perpendicular; they are moreover all in the same plane.

(*b*) **Curved** surfaces are considered as being made up of an infinite number of **plane** surfaces, and the effects of such are easily deduced from simple geometric laws. The following are some of the general facts: — Concave mirrors cause rays of light falling upon them to converge (approach each other); convex mirrors render these rays divergent; parallel rays falling upon a concave mirror are brought to a point midway between the centre of curvature and the surface, called the principal focus; conversely a luminous body, at the principal focus has its pencil converted into a beam. The image seen in a concave mirror is erect and larger than the object when the latter is near the mirror (nearer than the principal focus); when more distant, it is inverted and smaller. The image seen in a convex mirror is always erect and smaller than the object.

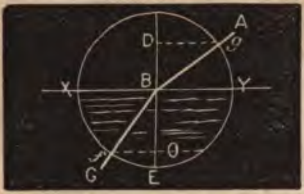
These remarks are true only within certain limits. The subject of the aberration of spherical mirrors, the effect of cylindrical and other forms, need not be discussed in an elementary work.

24. **Applications.** — The speculum is a tube with a polished interior surface, intended for the exploration of

the natural canals, as the nostril, the *meatus auditorius*, the vagina, and the rectum; the tube distends or keeps open the natural canal, while the polished interior reflects light within. Plane mirrors are used for obtaining images of parts out of the direct view, as in the laryngoscope and endoscope, by means of which the condition of the larynx or urethra may be thoroughly studied and applications made directly to it. Concave mirrors are used to concentrate light, as in the ophthalmoscope, where the light is thrown through the pupil; or in the use of the laryngoscope, where light is thrown into the fauces by means of a concave mirror fastened to the forehead of the operator, or placed in some other convenient position, while the organ itself is reflected in a plane mirror.

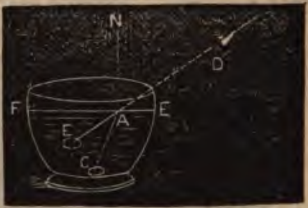
25. **Transmission.** — Light falling upon a transparent medium passes through it; practically, a portion is reflected, and this amount increases with the angle of incidence. When it falls perpendicularly, the ray passes through without change; when obliquely, it is *refracted* or bent. In passing from a rarer to a denser medium, the refraction is towards the normal, and *vice versa*. The relation between the angles formed by the incident and refracted ray with the normal, which expresses the refracting power of the body, is termed the *index of refraction*. Thus in Fig. 2 we have, A B D the angle of incidence, X Y the surface of the medium (water for instance), B G the refracted ray, D B E the normal; D g is the *sine* (or measure) of the angle of incidence, and O f of the angle of refraction, G B E. $\frac{D\,g}{O\,f}$ = index of refraction, which, for water is about $\frac{4}{3}$, or 1·33. Hence, as the eye always sees an object in the direction in which the ray of light enters it, objects viewed obliquely in water (or other media) are not seen in their true position. In denser media they seem nearer the surface, as in an oar in water. This

Fig. 2.



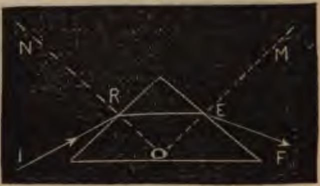
can be understood by the accompanying figure. The ray proceeding from the coin C, at the bottom of a dish of water, passing into the rarer medium, air is refracted from the normal and takes the direction A D; the eye at D traces the ray back in the direction of the dotted line, and sees the coin at E nearer the surface.

Fig. 3.



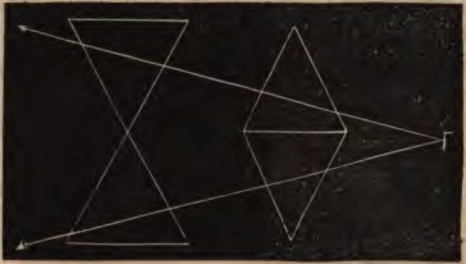
26. Prisms, Lenses.—When a ray of light passes through a triangular prism, it is refracted toward the normal on entering, and from the normal on leaving.

Fig. 4.



Thus in Fig. 4 the incident ray I R is refracted in the direction R E on entering the prism, and E F on leaving it. The effect of two prisms base to base, or edge to edge, is seen in Fig. 5.

Fig. 5.



Lenses are of various forms, the most important of which are the doubly convex and doubly concave.

The action of lenses is easily understood by considering them as made up of prisms arranged as in Fig. 5.

Rays of light, falling upon a convex lens, will be converged. Parallel rays, falling upon a doubly convex lens, are brought to a point called the principal focus, which coincides with the centre of curvature; Fig. 6. A concave lens causes parallel rays to diverge; Fig. 7.

Fig. 6.

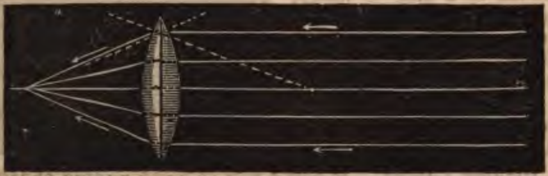
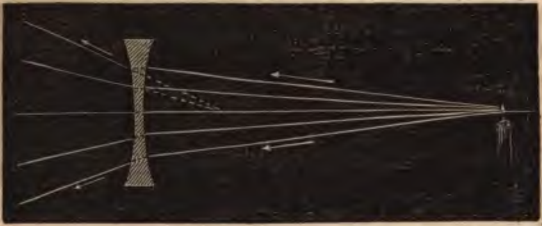


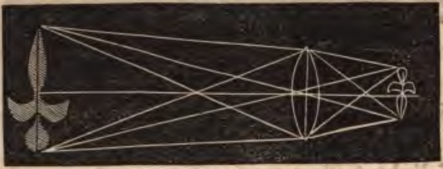
Fig. 7.



Images formed by Lenses. Each point of the object may be considered as giving off a pencil of rays, which are refracted to a focus; the assemblage of these foci gives the image of the body

When the object is beyond the principal focus of a convex lens, the image will be on the other side *real* and *inverted*; Fig. 8. Its size will depend upon the relative

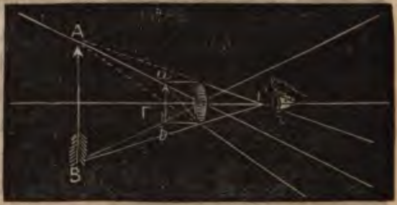
Fig. 8.



distances of the object, the lens, and the screen. The nearer the object to the lens, and the more distant the screen, the larger the image. When the object is nearer the lens than the principal focus, the image will be *virtual* (that is, it cannot be thrown upon a screen) on the same side as the object, and larger; the lens then constitutes a magnifying-glass. The image formed by a concave lens is virtual and smaller than the object.

Thus, in Fig. 9 the rays of light from the various points of the small arrow, *a b*, are refracted in passing through the doubly convex lens, the eye traces them backwards, and the image formed on the retina is the same as that of the object increased in its dimensions to A B, and viewed by the unassisted eye.

Fig. 9.



27. **The Eye** contains a series of lenses which cause the image of objects to be thrown inverted upon the retina. As we see bodies in the direction in which the ray comes, this does not interfere with vision.

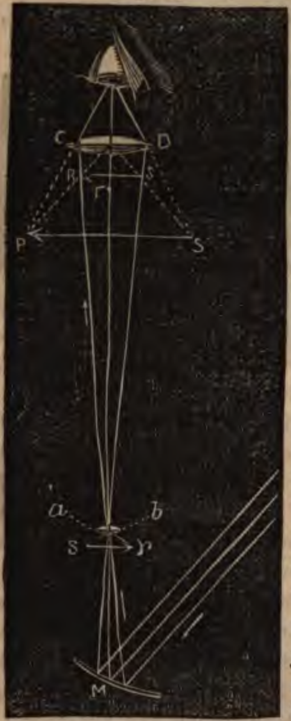
When the eye is too convex, the image is formed in front of the retina, and near-sightedness results. It is palliated by the use of concave spectacles, which cause the rays of light to diverge before entering the pupil. When the eye is not sufficiently convex, the rays do not come to a focus upon the retina, but would form an image behind it; convex lenses are used in these cases. Sometimes the eye is flattened vertically or at the sides, when objects are distorted, being elongated or rendered broader, as the case may be; some eyes are unable to distinguish the upright lines of a brick wall; others, those which are horizontal. Similar effects are often seen in looking through a window of common (cylinder) glass. In these cases cylindrical lenses are to be employed.

The first or second defect is often combined with the third.

Care should be taken, in selecting lenses to remedy defects of vision, that the eye is not still further injured by the use of spectacles of improper curve. Lenses with the cylindrical and concave or convex surface combined are made by Mr. Zentmeyer of this city.

28. **Aberrations.**—Simple lenses are subject to spherical and chromatic aberrations. The former produces indistinctness of form, the latter gives fringes of colour to the image. The causes and remedies of these will not be discussed here.

Fig. 10.

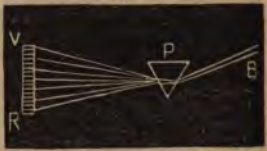


29. **Microscopes.**—The simplest form of microscope is the doubly convex lens, the object being placed within the principal focus (30). Sometimes the lens is mounted on a stand, with a stage to hold the object, and a concave mirror below to concentrate the light upon transparent bodies, or a convex lens above to illuminate those which are opaque.

The compound microscope consists of two sets of lenses, by the first of which (the object-glass) a real inverted image of the object is made, which is received at the focus of the second set of lenses (the eye-piece), and again magnified. The principle is seen in Fig. 10. When the arrow, *s r*, placed before the lens, *a b*, but without its principal focus, forms a real enlarged image, R S, which being again magnified by the eye lens, *c d*, the eye traces the rays back in the direction C R′ and D S′, giving the greatly enlarged image R′ S′. In practice, the instrument is made more complex, to avoid aberrations.

30. **Analysis of Light; Spectrum.**—If a beam of light, B, Fig. 11, be admitted into a dark room, through a circular opening, H, it will form a white spot upon the wall, W. If the triangular prism, P, be interposed, the beam will be twice bent (28); but instead of forming only a circular spot upon the wall, it will be elongated, forming what is termed the *prismatic spectrum*. The colours beginning at the top are violet, indigo, blue, green, yellow, orange, and red. By means of a lens or a second prism these may be re-combined, forming white light. These colours cannot be further decomposed; they are therefore termed *primary*. The violet, being the most deflected from the course of the beam, is the most refrangible, and the red the least so. The greatest *illuminating* power is in the *yellow*; the greatest *heating* power in and beyond the *red*, and the greatest *chemical* power in and beyond the *violet*. The lengths of the waves of the different colours, and their number of vibrations per second, have been calculated. The number of vibrations of the extreme violet is 727,000,000,000,000, and their length $\frac{1}{59750}$ of an inch; the extreme red vibrates 458,000,000,000,000 times per second, and the vibrations are $\frac{1}{37640}$ of an inch in length. This subject will be further discussed under the head of CHEMICAL AFFINITY, and DECOMPOSITION.

Fig. 11.



Complementary Colours. Any two colours which by their union would produce white light are said to be *complementary*. If we take from the solar spectrum any colour whatever, we may unite all the remaining colours by means of a lens or prism, and the resulting tint will be complementary to the one removed, being just what is wanted to make white light. The following are examples: red, green; violet, yellow; blue, orange. Complementary colours brighten each other by contrast.

31. **Absorption of Light.**— When light is reflected or transmitted, a portion is absorbed by the surface or medium. When all the rays are absorbed by a surface, it is black, or more properly invisible; when all are irregularly reflected, it is white, or if regularly reflected, invisible (23). If a portion be absorbed, the colour will be due to those rays reflected or transmitted; thus blue glass absorbs all but the blue ray, and red cloth absorbs all but the red ray. The cause of this selection of colours of bodies is wholly unknown.

32. **Physical Optics** includes the subjects of interference, diffraction, polarisation, and fluorescence. These phenomena are complex in their character; they are usually explained upon the undulatory theory, although in some cases it fails. The student is referred to more elaborate works for their consideration

HEAT.

I. PRELIMINARY.

33. **Nature of Heat.**— Two theories have prevailed: First, that a subtile imponderable body, termed *caloric*, enters into the pores (8) of bodies, and by its varying quantity and the changes produced upon its entering or leaving, the phenomena observed are caused. In certain cases it was supposed to become latent (Lat. *lateo*, I lie hidden), and was then inappreciable to ordinary observation. The second considers heat as a "mode of

motion,"* but the exact manner in which this motion produces the various phenomena is yet a matter of discussion. The latter view of the subject is generally adopted, although, as in the case of light, the language of the material theory is yet employed for convenience.

34. **Relations of Heat and Motion.** — Apart from any theoretical consideration, the mutual convertibility of motion and heat has been settled by experiment. It has long been known that heat would produce motion, as in the steam-engine, or the expansion of a liquid in a thermometer tube, and that arrested motion would produce heat, as in friction-matches, or iron rendered red-hot by hammering. It has been ascertained that when heat is doing *work*, it is no longer sensible as heat, and that the amount of heat developed by arrested motion is exactly equivalent to the force employed; which force is equal to that which would be developed by the amount of heat given out by its arrest.

35. **Mechanical Equivalent of Heat.** — The independent researches of Joule and Von Meyer have given us the mathematical relation between heat and work. The unit of work (dynamical unit) is one pound raised one foot, or one foot-pound; the unit of heat is the amount necessary to raise one pound of water from 32° to 33° F. or less, accurately that required to raise a pound of water one degree of Fahrenheit's scale. One thermal unit is equivalent to 772 dynamical units.

36. **Temperature.** — We judge of the *intensity* of heat by our sensations, and speak of bodies as being hot or cold. These sensations are fallacious, those produced by extreme cold and heat being similar. The terms *high* and *low temperature* are applied to signify the conditions expressed in ordinary language by *hot* and *cold*. The tem-

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* TYNDALL. *Heat considered as a Mode of Motion.* 1863.

perature of a body simply indicates the intensity of its heat, and gives no idea of the quantity. Thus a thermometer in a teacupful of boiling water marks the same temperature as if plunged into a vat of the same containing a thousand gallons, yet we know that the quantity of heat given out during the cooling of the latter is as many times greater than that which the former gives out, in falling to the same temperature, as the amount of liquid is greater. Again, suppose a thermometer at 50° F. and 100° F. in equal quantities of liquid, it would be a mistake to suppose that in the latter case the water was twice as hot as in the former. The zero of the thermometric scale is entirely arbitrary and does not indicate the complete absence of heat, which may be yet abstracted from bodies which have been cooled to 0. The absolute 0 of heat has been calculated to be — 459° F.

37. **Measurement of Temperature.**—The instruments for indicating changes of temperature, or for measuring them, are *thermoscopes*, *thermometers*, *pyrometers*, and *thermo-multipliers*. In all cases their graduations are arbitrary.

Thermoscopes (Gr. *therme*, heat, and *scopeō*, I view) merely indicate changes of temperature. The most common form is a bulb containing air attached to a stem containing liquid; on an increase of temperature the air expands, driving the liquid upwards or downwards, (Sanctorius' thermometer.) This instrument is imperfect, because the volume of air in the bulb may be varied by changes of atmospheric pressure. In the differential thermometer two bulbs containing air are united by a U-shaped tube containing liquid; any change in the temperature of one of the bulbs, the other being unaffected, is made manifest by the motion of the liquid from the warmer bulb.

Thermometers (Gr. *therme*, heat, and *metron*, measure) serve both to indicate and compare changes of temperature. Their indications are derived from the expansion of a liquid in a closed tube. Mercury is the liquid preferred because of its low specific heat (69), its uniformity of expansion (51), its low freezing and high boiling point, and its property of not adhering to glass. The tube has a bulb blown on it, which with part of the stem is filled with mercury; the air is expelled by boiling the mercury, and the end of the tube hermetically sealed, (melted together.) The instrument is then immersed in the vapour of boiling water, (the barometer being at 30 in.,) and the height of the column marked; afterwards it is plunged into melting ice and the height again noted. The space between these two points is divided into *degrees*, which vary according to the scale adopted. On the centigrade scale (C.) the melting point of ice is marked 0, the boiling point of water 100°. Reaumur's scale (R.) has the same 0, but the boiling point is 80°. Fahrenheit (F.) marks the lower point 32°, the upper 212°. Thus the same space is divided into 100, 80, and 180 degrees on the different scales.

Hence (dividing by 20) 9 degrees F.=5 C.=4 R. To convert C. degrees to F., multiply by 9, divide by 5, and add 32. To convert R. to F., multiply by 9, divide by 4, and add 32. The following formulas include all the necessary conversions: F. to C., $\frac{5}{9}(F.-32)=C.$; C. to F., $\frac{9}{5}C+32=F.$; R. to F., $\frac{9}{4}R.+32=F.$; F. to R., $\frac{4}{9}(F.-32)=R.$

Pyrometers (Gr. *pur*, fire, and *metron*, measure) are instruments used for measuring high temperatures by means of the expansion of a solid body, which it is difficult to soften or melt. Saxton's reflecting pyrometer measures very slight changes at ordinary temperatures by communicating, by means of compound levers, the motion produced by the expansion of a bar of metal to a mirror which reflects a scale placed at a distance; the image of the scale in the mirror is examined by a telescope.

An idea of the effect of the mirror in magnifying the changes of the bar, may be obtained by throwing a beam of light from a small looking-glass upon a distant wall; an almost imperceptible change in the position of the mirror is followed by a motion of the spot of reflected light through several feet.

Thermo-Multiplier. This instrument is by far the most sensitive to minute changes of temperature yet devised. A number of small bars of bismuth and antimony are soldered at alternate ends and kept apart by slips of pasteboard; to the end bars of the arrangement a copper wire is fastened, this passes several times around a delicately suspended magnetic needle; when one end of the pile of bars is warmed, a current of electricity passes through the wire and causes the needle to move over a graduated scale.

II. SOURCES OF HEAT.

1. PHYSICAL; 2. MECHANICAL; 3. CHEMICAL.

38. (1) **Physical.**—These are the heat of the sun and stars, the internal heat of the earth, and atmospheric electricity. The two last are comparatively unimportant.

Amount of Heat Emitted by the Sun.—According to the observations of Pouillet,* the amount of heat annually received from the sun would melt a layer of ice surrounding the earth 101 feet thick. Yet the earth receives less than the two thousand millionths of the heat emitted by the sun. The fixed stars, the suns of other systems, are estimated to furnish to the earth four-fifths as much heat as the sun itself.†

The heat emitted by the sun would boil 700,000,000,000 of cubic miles of ice-cold water per hour; its volume is 1,400,000 times greater than that of the earth, yet if made of coal, and oxygen furnished in quantity sufficient to enable it to supply the observed emission, it would be utterly consumed in 5000 years.‡

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* *Physique*, tome 2de, p. 681. † SILLIMAN, *op. cit.* 493.

‡ TYNDALL, *op. cit.* 434, 435.

The cause of the sun's heat is supposed by Von Meyer [*] to be due to the percussion of asteroids falling upon it. Should the earth be drawn into the sun, the heat developed by the shock and the arrest of the earth's rotation would supply the sun's emission for ninety-five years.[†]

39. (2) **Mechanical Sources of Heat.**—Force is never lost. When motion is arrested, enough heat is developed to reproduce that motion, if properly applied. Friction compression, and percussion are methods of converting motion into heat.

A match is lighted by the heat developed by friction; a piece of cold metal passed between rollers becomes hot; iron may be heated red-hot by hammering.

40. (3) **Chemical Sources of Heat.**—Chemical combination is accompanied by heat. When the heat thus produced is sufficiently intense to produce light, the phenomenon is called combustion. This subject will be more fully considered under the heads of CHEMICAL AFFINITY, and OXYGEN.

In an ordinary fire the heat developed is due to the union of the oxygen of the air with the carbon and hydrogen of the fuel. The amount of heat developed will depend chiefly upon the quantity of oxygen consumed.

The cause of animal heat is supposed to be the union of the carbon, and perhaps of the hydrogen of the food, with the oxygen of the inspired air. This probably takes place in the capillaries.—(LIEBIG.) This view is not adopted by all physiologists.

III. COMMUNICATION OF HEAT.

1. RADIATION; 2. CONDUCTION; 3. CONVECTION.

41. (1) **Radiation.** — The phenomena of radiant heat closely resemble those of light. It is propagated in rays

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[*] *Celestial Dynamics*, Am. ed., p. 271.

[†] Prof. THOMPSON, cited in TYNDALL, pp. 441, 442.

with immense velocity, and is reflected, transmitted, or absorbed by the surface upon which it falls. It is not affected by currents of air. Its intensity is directly proportional to the temperature of the source, and inversely as the square of the distance. It is supposed to be constantly taking place from the surfaces of all bodies; when a body is warmer than those surrounding, it emits more than it receives, and *vice versa*. Hence the apparent radiation of cold, as in the lowering of the thermometer hung over the side of a vessel on the approach of an iceberg. The heat accompanying light is termed *luminous;* that from a dark body, as a vessel of hot water, *obscure*.

42. **Emission.**—The rate at which heat passes from a body depends upon the temperature and nature of the surface. Rough surfaces emit most rapidly. The following examples will show the emissive power of different surfaces for non-luminous heat: Lampblack (the highest) assumed as 100; white lead, 100; writing-paper, 98; glass, 90; ice, 85; tarnished lead, 45; polished silver, 3. It is independent of colour.

Water is easily boiled in a glass, or rough or smoked metallic vessel; it is kept warm in a vessel of polished metal. A polished metallic vessel, filled with hot water, will cool more rapidly if covered with a tightly fitting muslin jacket. The high radiating power of glass causes windows, in winter, to cool the air of rooms rapidly, resulting in loss of fuel and the production of downward currents of cold, foul air, which interfere with ventilation. Water has a high radiating power, and will freeze, under favourable circumstances, when the temperature of the surrounding air is not below 40° F.

43. **Absorption.**—The absorbing power of a surface is the same as its emissive power when the source is at 212° F.; at other temperatures they coincide nearly, but not exactly. It also varies with the nature of the source. Lampblack is the only substance which absorbs all the rays of heat, no matter what the source. Absorption of

obscure rays is independent of the colour of the surface; of *luminous* rays the greatest number are absorbed by black; then in the following order: violet, indigo blue, green, red, yellow, and white. The rays of heat are more largely absorbed in proportion as they fall more nearly perpendicularly upon the surface. Hence the less apparent warmth of the sun's rays in winter.

44. **Reflection.**—The laws of the reflection of radiant heat agree with those of light (23). The reflecting power of a surface is inversely as its radiating power. Polished metallic surfaces form the best reflectors; glass silvered on the back, while an excellent reflector of light, is almost useless in the case of heat; but a film of gold $\frac{1}{200000}$ of an inch in thickness, placed on the front of the glass, will reflect almost as well as a solid metallic plate.

45. **Transmission.**—The laws of the transmission of radiant heat accord closely with those of light. Bodies which allow heat to pass through them are termed *diathermous* (Gr. *dia*, through, and *thermainō*, to heat). There is no direct relation between the transparency of a medium and its power to transmit heat. Rock-salt is the most diathermous body known; when smoked so as to become opaque, it still transmits heat; alum which may be obtained quite transparent, almost entirely cuts off the heat-rays; glass transmits them imperfectly. The proportion of heat-rays transmitted also depends upon the source; at high temperatures a larger proportion is transmitted, and the difference of the diathermacy of various media is less marked than for the obscure rays. Gases vary exceedingly in their transmitting power, pure dry air being almost absolutely diathermous, while ammonia, olefiant gas, odours of essential oils, and watery vapour obstruct to a greater or less degree.* The radiating and absorbing powers of media are proportional.

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* Tyndall, *op. cit.* pp. 361, 374, 399.

Calling the absorptive power for obscure rays, under atmospheric pressure, of pure dry air 1, that of ammonia is 1195; olefiant gas, 970; humid air, 96; essential oils, 30 to 372. A stratum of ammonia as thick as a sheet of paper will cut off obscure heat-rays as effectually as a metal screen. The importance of these discoveries to the science of meteorology is obvious.

SIFTING OF RAYS.—When the rays from any source pass through a medium, a certain portion is arrested. Of those which go through a much larger proportion will pass through a second similar medium. For example, a plate of alum transmitted but 9 per cent. of heat-rays, arresting 91; of these 9 a second plate transmitted 90 per cent., arresting but 10 per cent. The heat which has passed through the first plate is said to be sifted of those rays which are most easily arrested. This principle explains why glass readily transmits solar heat, but arrests that from other sources. The heat of the sun in its passage through the atmosphere (which contains watery vapour, ammonia, and odours) is strained of the rays which could be stopped by the glass.

46. **Refraction of Heat.**—The rays of heat obey the laws of light in regard to refraction. The ordinary burning-glass causes the rays of the sun to be concentrated upon a spot, the focus (26). The intensity of the heat at the focus compared with that of the sun is as the area of the glass compared with that of the focus. Heat passed through a prism forms a thermal spectrum analogous to the solar spectrum, but differing in many important points. Heat, like light, may be polarized.

47. **Conduction.**—Heat passes slowly through bodies, it is supposed by radiation from particle to particle. The conducting power of liquids is very slight, that of gases inappreciable. Of solid bodies, the metals are the best conductors. The following list assumes the best conductor at 100: Silver, 100; gold, 98; copper, 73; brass, 22; tin, 23; iron, 13; lead, 11; platinum, 10; German silver, 6; bismuth, 2. Solids generally conduct equally in all directions. This is not the case with certain crystals and with wood. Porous or fibrous bodies, as sawdust, pow-

dered charcoal, and down, are bad conductors on account of the air and gases enclosed.

Illustrations. — If a rod of iron be held with one end in the fire, an appreciable time will elapse before the hand receives heat through it, although the radiant heat of the sun, at 95,000,000 of miles distant, is felt as soon as his light is seen.

If a pin be thrust into a candle-flame, it will soon become too hot to be held; a wooden match, if held upwards, may be burned almost to the fingers without heat being communicated by the wood.

Metal at 120° F. will burn the hand; water may be borne at 150° if the hand be kept still and the temperature gradually raised; dry air may be endured above 300°, at which temperature eggs may be roasted and steaks cooked. Moist air conducts better than when dry; hence the feeling of chilliness it produces. Fire-proof safes, ice-houses, water-pitchers, are made double with porous material interposed to prevent the communication of heat from without. A bed of ice several centuries old exists on the flanks of Mount Ætna, preserved by having been first covered with a layer of sand and ashes, and then with a stream of lava.

The order of conducting power of clothing materials is as follows: linen, cotton, silk, wool, furs, eider-down. Fine fabrics are warmer than coarse ones.

48. **Convection or Circulation.** — Liquids and gases can, in practice, be warmed only by heat applied below. The particles of fluid in contact with the heated portion of the containing vessel become expanded and are forced upwards by the descending cooler and heavier ones. A circulation is thus set up by which each particle in turn receives heat from the source. The presence of any viscid matter will prevent this circulation; hence, in boiling starch, gum, etc., the fluid requires to be constantly stirred to prevent burning.

Winds and currents in the atmosphere (193) are thus caused. The gulf-stream is due to the heated water of the tropics flowing off toward the poles.

IV. EFFECTS OF HEAT.

49. In considering the effects of heat, it should be borne in mind that bodies consist of particles with disproportionately large spaces or *pores* between them (8). These particles are under the constant influence of two forces, that of attraction tending to bring the particles into contact, and that of repulsion (due principally, if not wholly, to heat) tending to drive them asunder. When the first preponderates greatly, bodies are solid; when in a less degree, liquid; and when the latter is stronger, they are in the state of gas or vapour. Moreover, as the distance of the particles increases, the attractive force diminishes in a rapid ratio, and the repulsive force acts with an energy correspondingly greater (9). The effects of heat may be considered under the heads of EXPANSION, and CHANGE OF STATE.

50. 1. EXPANSION (*a*) OF SOLIDS, (*b*) OF LIQUIDS, (*c*) OF GASES.

(*a*) **Of Solids.**—All solids (except caoutchouc *) expand by heat. The expansion is equal in all directions; the solid resumes its original form and volume on returning to the original temperature. When expansion is measured in length only, it is called linear; when in all dimensions, it is called cubical. The *coefficient* of expansion is the small increase in dimensions observed in passing from 32° to 33° F. The rate of expansion of solids varies with the body and increases with the temperature. The force exerted by an expanding or contracting body is equal to that required to extend or compress it an equal amount, and is practically irresistible. A bar of iron one inch square, heated from 10° to 90° F., exerts a pressure of about 7 tons.

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* TYNDALL, *op. cit.* p. 102.

Certain crystals do not expand equally in all directions. *Wood* expands more in the breadth than in the length of its fibres; *lead* sometimes expands permanently, causing the leaden lining of bath-tubs, etc., to become wrinkled.

Cubical expansion may be derived from the linear by cubing the coefficient. The increase of capacity of hollow vessels is equal to that of a solid mass of the same size and material for a like change of temperature.

The amount of expansion of solids is small, being for zinc, which is the most expansible of the metals, only $\frac{1}{340}$th of its length, between 32° and 212° F. The following list gives the relative dilatability of the bodies named: Zinc, lead, tin, silver, brass, gold, copper, bismuth, iron, steel, antimony, platinum, glass. Ice and certain minerals are more expansible than the metals. Platinum wires may be fastened in glass, as the two expand and contract nearly alike; other metals will expand and contract more than the glass, causing them to split it or become loose.

Compound bars.—If two metals, as silver and platinum, be riveted together, the bar will bend on change of temperature; the more expansible metal forming the convex front of the curve when heated, and *vice versa.* Such an arrangement is employed in *Breguet's* thermometer, and is applied, among others, to the compensation of the pendulums of clocks and balance-wheels of watches.

The force of expansion and contraction of solids is often usefully employed, as in shrinking tires on wheels, reinforce rings on cannon, or in drawing up the walls of buildings by the contraction of rods passed through the walls. Glass stoppers may be loosened by heating the neck of the bottle; the neck becomes warmed sooner than the stopper, and, expanding, releases it. Heat, applied to a thick glass vessel, will crack it, because of the more rapid expansion of the part heated, owing to the bad conducting power of the glass. Chemical flasks are made thin, and will safely bear sudden changes of temperature.

51. (*b*) **Of Liquids.**—Liquids expand more than solids for an equal increase of temperature, because in them the cohesive force is weaker. Between 32° and 212° F. the expansion (cubical) of mercury is $\frac{1}{50}$, of water $\frac{1}{21 \cdot 3}$, alcohol $\frac{1}{9}$. They expand more irregularly than solids, the rate being greater at higher temperatures. Mercury is the most uniform in its rate of expansion, which is one reason for

its use in thermometers (37). The rate of expansion of a liquid in glass (which at the same time expands) is called its *apparent*, in contradistinction to its *absolute* or real expansion. The force exerted by the expansion of a liquid is, like that of a solid, practically irresistible. Mercury, heated 10°, exerts a force of 2850 lbs. per square inch. When kept under pressure, and heated above their boiling-point, the rate of expansion of liquids increases rapidly, and even exceeds that of gases. Liquid carbonic acid expands more than air for an equal increase of temperature.

52. **Maximum Density of Water.**—Water, cooled below 39·2° F., no longer contracts, but expands until it reaches the freezing-point 32° F. Hence at that point any increase or diminution of temperature causes an increase of bulk, and the liquid is said to be at its temperature of maximum (greatest) density

Owing to this fact, our streams and lakes never freeze to any great depth. Water exposed to cold loses its heat by radiation (41) and convection (48), until it reaches 39·2° F.; after this, circulation ceases, the colder water, being lighter, no longer sinks to the bottom, but remains like a film of oil on the surface until it freezes. Ice, being lighter than water floats, and as it is a bad conductor of heat, acts to protect the stream from further loss. The temperature of maximum density of sea-water is 25·7° F.

53. (*c*) **Of Gases.**—In gases the cohesive force is inappreciable; they therefore expand more than liquids. All gases expand alike, and the rate is not altered by temperature nor pressure. The increase of bulk of a gas for 1° F. is $\frac{1}{460}$ of its bulk at 0° F., or $\frac{1}{492}$ of its bulk at 32° F. This is equal to rather more than one-third of the bulk between 32° and 212° F.

The above statements, although practically true, are not strictly so Certain liquefied gases, as carbonic acid, expand more than the gases themselves. All gases do not absolutely expand alike, nor is the rate of expansion entirely uninfluenced by pressure.

In order to calculate the volume of a given quantity of gas of known temperature and pressure at any other temperature and pressure, the following simple formulæ will be sufficient. Calling t the original temperature in degrees F., p the original pressure, t' the observed temperature, and p' the observed pressure. Then, as a gas increases $\frac{1}{460}$ of its bulk for each degree F., and its volume is inversely at the pressure (194), we have

$$460+t : 460+t' :: V : V' : \text{and}$$
$$p' \quad : \quad p \; : :: V : V'$$

where V and V′ are the original and observed volumes.

Thus, 100 cubic inches of a gas at 60° F., and 30 in. bar., become at 90° F., and 29 in. bar.,—109·2 c. in.

$$520 : 550 :: 100 : 105{\cdot}7$$
$$29 : \;30 :: 100 : 103{\cdot}5$$

54. 2. **Change of state** includes the phenomena of (*a*) fusion, congelation, or solidification; (*b*) evaporation, vapourisation, condensation; and (*c*) latent heat. All matter (with certain exceptions) may exist either as solid, liquid or gas, the *state* depending upon the temperature and pressure. By lowering temperature and increasing pressure, thus aiding cohesion, we convert gases and vapours into liquids, and finally into solids, and *vice versa.*

As yet, some solids have not been satisfactorily fused or vapourised, and the following gases have resisted all attempts to liquefy them: oxygen, hydrogen, nitrogen, carbonic oxide, nitric oxide, and marsh gas.

When we speak then of a body as a solid, or liquid, or gas, we refer to ordinary temperatures. To an inhabitant of a climate of a fixed temperature of 0° F., sulphurous acid would be a liquid and water a solid; were the planet Mercury habitable, iron would be described as a gas

55. (*a*) **Fusion and Solidification.**—Bodies melt at a certain temperature fixed for each, at which temperature they also solidify. During the processes of fusion or of solidification, the temperature remains constant. Some bodies, as ice, pass at once to the liquid state; others, as butter, soften gradually; others, as camphor and arsenic,

pass at once into the state of vapour, unless under more than atmospheric pressure.

The following are some of the more important *fusing points* in degrees (F.): Mercury—39, bromine — 4, phosphorus ×111, iodine + 224, sulphur + 239, tin + 455, bismuth + 518, lead + 630, zinc + 761, silver + 1873, copper + 2143, gold + 2016.

The temperature of the liquid remains constant during fusion because the heat applied goes to melt the body, not to raise the temperature of that already melted. It is then doing work (34) and is not sensible to the thermometer; (LATENT HEAT.) Conversely, when heat is abstracted from a liquid, a portion becomes solid, and the heat of fusion is thus liberated, and the temperature cannot fall so long as any liquid remains.

Bodies which are difficult of fusion, as carbon, fire-clay, lime, magnesia, silica, etc., are termed *refractory*. Even carbon, however, has been softened and partially fused in the voltaic arch.

56. **Change of Volume during Solidification.** — Mercury and most metals contract on solidification, and do not therefore make good casts. Hence coins and medals are stamped. Certain alloys, as type-metal (lead and antimony), expand and take sharp impressions of a matrix. Water expands about one-eleventh of its bulk on freezing, and will burst strong iron vessels.

Water does not always freeze at 32° F., but invariably melts at that temperature. By keeping it perfectly still, deprived of carbonic acid, or under great pressure, or in capillary tubes, its temperature may be lowered 10° or more below its normal freezing-point.

57. (*b*) **Evaporation and Vapourisation.** — Liquids on the application of heat become vapours. Physically, vapours (remote from their condensing points) and gases are identical

Evaporation takes place gradually, at all temperatures, and from the surface of the liquid only. When solids pass at once into the state of vapour, it is termed *sublimation*, although this word has a more extended meaning

Ice and snow evaporate below 32° F. Some liquids do not evaporate below a certain point, as mercury below 40° F., and sulphuric acid at common temperature.

58. **Tension of Vapours.** — If a barometer tube be filled and inverted over mercury, there will be above the mercury, in the tube, a vacuum (Torricellian vacuum [193]). If into a series of such tubes small equal quantities of different liquids be introduced at the same temperature, it will be noticed that the liquid will volatilise instantly, and that the mercury will be forced down in the tube to a greater distance in proportion as the liquid is more volatile. This elastic force or spring of the vapour is called its *tension*. If an additional quantity of liquid be introduced, further depression takes place, until it will be found that the liquid will no longer volatilise, nor the column be depressed by its vapour. The space has become saturated with the vapour and can receive no more; this is called the point of saturation or maximum (greatest) tension of the vapour for that temperature. By increasing the temperature, more liquid is volatilised and further depression takes place; by reducing it, a portion of the vapour is condensed, and the column rises. When the temperature rises to the boiling-point of the liquid, the mercury is driven out of the tube, and will stand at the level of the cistern. When the tube contains both vapour and liquid, by raising it so as to diminish the pressure, further evaporation takes place; by depressing it into the cistern so as to increase the pressure, more liquid is formed. Hence the point of saturation or maximum tension varies with the temperature, and is independent of the pressure. The tension of vapours in communicating vessels unequally heated is equal, and is that due to the lower temperature.

59. **Circumstances influencing Evaporation.**— The greater the extent of surface, the higher the temperature (up to a certain point [64]) and the less the pressure, the more rapid the evaporation. Rapid removal of air, by presenting a fresh space instead of one partially saturated, also aids it.

In the arts, evaporation is carried on in flat dishes; sometimes in salt-making the brine is allowed to trickle over twigs, to increase the extent of surface. Medicinal extracts are prepared in vacuo. Draughts of air produce a sensation of coolness by promoting evaporation (68).

60. **Vapourisation,** or **Ebullition,** takes place rapidly at the boiling-point and from the whole of the liquid. A liquid boils when the tension of its vapour exceeds its cohesive force and the pressure on its surface. When water is exposed to heat, we notice that the air is first driven out, then *simmering* is heard. This is due to the condensation of the bubbles of steam formed at the lower part of the vessel by the cooler liquid above. As soon as the whole reaches the boiling-point, the bubbles pass to the surface and the steam escapes; ordinarily it is partly condensed into minute bubbles or drops forming a cloud. True steam is transparent and invisible, as air. The boiling-points of liquids will be given as their properties are described. By reducing the pressure the boiling-point is lowered, by increasing it it is raised, so that water may be made to boil in vacuo at 70°, or in a strong boiler be heated red-hot. The temperature of water in an ordinary locomotive boiler is 340° F.

Adhesion also modifies the boiling-point. In a perfectly clean glass vessel water may be raised to 221°, and then bursts irregularly into steam; a little clean sand or platinum wire causes the liquid to boil regularly at its normal temperature. This expedient is often used in distilling heavy liquids, which by their thumping would break the retort. Water entirely deprived of air may be heated to 360°, and then bursts into steam with explosive violence. — (DONNÉ.)

As the boiling-point varies with the *pressure*, the barometric height of 30 inches (193) is assumed as the standard.

Solutions of solids raise the boiling-point; a saturated solution of common salt boils at 227° F. Such solutions are sometimes used as water-baths or in tempering steel. The water-bath consists of two concentric vessels having the intervening space filled with water, but open to the atmosphere. A body placed in the inner vessel will be subjected to a temperature not exceeding that of the boiling-point of the liquid. The common glue-pot is an example.

Sugar is made in vacuum pans, by means of which it is boiled at a lower temperature. In Papin's digester, a strong boiler of peculiar form, water is heated above its boiling-point, and its solvent action on certain bodies much increased.

61. **Mechanical Force developed during Evaporation.**— A cubic inch of water yields nearly a cubic foot of steam. Hence the evaporation of water is a convenient method of converting heat into motion (34). Although some other liquids boil at a much lower temperature, ether, for instance, at 94·8°, yet at their boiling-points, the space occupied by their vapour is less than that of steam, and they require the same amount of heat to produce the same volume. Hence there would be no advantage in substituting them for water in engines. The expansion of air is employed for the same purpose. As air only increases about one-third of its volume by being heated from 32° to 212° F., its usefulness is limited to engines of moderate power. Its advantages over steam are: (1) Greater economy. The specific heat of air (70) is but one-fourth that of water. In engines working into the atmosphere, the agent (steam or air) is thrown away after doing work, and the residual heat wasted. Air wastes but one-fourth as much as steam. (2) Safety. In air-engines there is no boiler, can be no explosion, and an attendant is only needed to replenish the fire and keep the machinery in order.

62. **Condensation** of vapours is accomplished by cold, aided in some cases by pressure. Pressure alone cannot liquefy a vapour, as the heat developed by the condensation is equivalent to the force producing it (34). By combined pressure and cold most of the gases known to us have been liquefied, and many solidified. Those which are known to us only as gases, to wit: oxygen, hydrogen,

nitrogen, carbonic oxide, nitric oxide, and marsh gas, are termed permanently elastic gases.

63. **Distillation** is the successive evaporation and condensation of a liquid. It is employed to separate a liquid from a dissolved solid, or to separate liquids of different volatility from each other (fractional distillation). An example of the first is in the distillation of water to free it from impurities; of the second, the separation of alcohol and water in the manufacture of spirits.

Fractional distillation cannot be relied on to separate entirely liquids of different volatility, because evaporation takes place below the boiling-point of the less volatile liquid. Hence chemical means are resorted to after the distillation. See ALCOHOL.

The form of condenser used on the large scale is a coiled pipe or *worm* immersed in a cistern in which water is admitted below, and passes out above. Liebig's condenser is a tube surrounding that leading from the retort, closed at the ends, and having a lateral tube for the admission of cold water below, and one for its exit above.

When the *distillate* is not very volatile, it is sufficient to keep the neck of the retort and the receiver cool by means of wetted paper or cloth.

64. **Spheroidal State.**—A liquid dropped upon a polished plate heated considerably above its boiling-point, does not wet the plate, but assumes the form of a flattened sphere resting quietly upon it. The evaporation of the spheroid is slow, its temperature is always below the boiling-point of the liquid (205·7° F. for water), that of its vapour nearly that of the plate. It does not touch the plate. The phenomenon takes place in vacuo, on the surface of most solids and of liquids. The chemical action of a liquid upon the plate is suspended while the former is in the spheroidal state. The causes assigned for this phenomenon are four. (1) The repulsive force which heat exerts between bodies which are nearly in contact with each other. (2) A cushion of vapour is formed on which the spheroid rests. (3) This vapour is a bad conductor,

and prevents the rapid transmission of heat from the plate to the globule. The radiant heat of the plate is reflected from the globule. (4) The evaporation from the surface of the spheroid carries off the heat as it arrives, and prevents the liquid from boiling.

Certain remarkable phenomena are connected with this state. A white-hot poker may be licked with impunity; the hand (moist) may be safely plunged into molten iron or lead. By the aid of liquid sulphurous or solid carbonic acids, water and mercury may be frozen in red-hot capsules.

65. (*c*) **Latent Heat.**—When heat causes a solid to liquefy, or a liquid to vapourise, it is doing work in overcoming or resisting the cohesive force of the particles. It cannot at the same time then do other work in expanding the liquid of a thermometer, or in producing those changes which give us the sensation of heat. It is therefore insensible or *latent* (*lateo*, lie hidden).

If we expose a pound of water and one of ice, each at 32° F., in vessels provided with thermometers, to an uniform source of heat, the ice will gradually melt, but the thermometer will remain at 32° until the last solid particle has disappeared (55). If at this instant the thermometer in the other vessel be examined, the water will be found to have risen to 174° F. It is evident that 142 thermal units (35) have been expended in converting ice into water of the same temperature.

If we expose a pound of water at 212° F., and 967 pounds at 60° F., to an uniform source of heat, the boiling water will pass into steam of the same temperature (212° F). When it has all vapourised, the 967 pounds of water will be found to have risen 1° F., to wit, to 61° F. Hence 967 thermal units are required to convert water into steam of the same temperature. On condensing the steam, by passing it into water below 212°, this heat is again given out.

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Water is the great regulator of changes of the earth's temperature. From its high specific heat (69), it absorbs heat in hot seasons or localities, and gradually gives it out as the temperature falls. Ice and snow give out their latent heat to moderate sudden frosts, and again absorbing it, reduce the temperature during rapid thaws. By their bad conducting powers they protect the earth from extremes of cold. Evaporation from the surface of the earth moderates the intensity of the sun's rays.

Steam is used as a source of heat, both from its convenience and in cases where the direct action of fire would be unsafe. It gives out both its sensible and latent heat when condensed. The sum of the sensible and latent heat is *nearly* constant; that is, as we increase the temperature of steam by means of a high-pressure boiler (60), we compress it into a less volume, and thus liberate a portion of the latent heat. Hence there is no economy in the use of high-pressure steam for heating purposes.

66. **Freezing Mixtures.**—If we mix two solids capable of rendering each other liquid by chemical or mechanical force, the particles are torn asunder by this force, and the heat which would be necessary to liquefy them must be supplied from surrounding bodies. The same is true of a solid and liquid. The most common and convenient freezing mixture is composed of salt one part, snow or pounded ice two parts. A temperature of 0° F. may thus be produced and maintained for some time. By means of a bath of solid carbonic acid and ether, Mitchell (J. K.) obtained a temperature of —146° F. Natterer, by means of liquid nitrous oxyde and bisulphide of carbon, reached —220° F. In the latter cases the low temperature was partly due to evaporation. The cold produced by solution, as of epsom salt or nitre, is explained on the same principle.

67. **Cold produced by Evaporation.**—The heat required to evaporate or vapourise a liquid is abstracted from surrounding bodies, or from the liquid itself. The more volatile the liquid, the more rapid the reduction of temperature.

The cooling effects of the rapid evaporation of perspiration, especially in draughts of air, of cologne, etc., are well known.

The evaporation of ether has been employed on the large scale in Twining's apparatus for the production of ice in hot climates. Water may be frozen by its own evaporation in an exhausted receiver, or the cryophorus of Wollaston. In Carré's apparatus a solution of ammonia in water (which takes up over 700 volumes of the gas) is heated in a strong boiler until the gas is expelled. This gas passes by a tube into a communicating condenser, where it is liquefied by its own pressure, aided by the abstraction of heat by means of a current of water. If the boiler be now placed in water, and cooled, the liquid ammonia (which boils at—40° F.) passes rapidly into vapour, which is absorbed by the now cool water in the boiler, and the water in contact with the condenser, giving heat to the boiling ammonia, freezes. The cold produced by the evaporation of the spray of ether or rhigolene has been used for the production of local anæsthesia.—(Richardson, Bigelow.)

68. SPECIFIC HEAT.—Equal weights of different substances submitted for the same time to the same source of heat do not acquire the same temperature. Some take longer than others to *warm through*. Thus if two vessels, one containing a pound of water, the second a pound of mercury, be exposed to the same source of heat, it will be found that while the water rises 1°F., the mercury will rise 33° F. The water is thus said to have a *capacity* for heat 33 times greater than that of mercury. As water has the greatest capacity for heat of any known body, it is assumed as the standard. The *specific heat* of a body is the amount required to raise it 1° F., compared with an equal weight of water. Thus the specific heat of mercury is 0.033. It is not necessary here to detail the various methods of determining accurately the specific heats of bodies. The specific heat of a substance is greater in the liquid than in the solid form.

A common experiment to show the different relative expansibility of liquids is to take three tubes of equal diameters furnished with bulbs of equal capacity, one filled with mercury, a second with water, and a third with alcohol, to the same mark on a scale. These are inserted in boiling water. At the end of a few minutes the alcohol will stand highest, the water next, and the mercury lowest, indicating their relative apparent expansibility. *At first*, however, the mercury rises higher than either the water or the alcohol, owing to its small specific heat. This is one of the properties which renders mercury especially adapted for thermometers. The high specific heat of water serves to moderate vicissitudes of climate (65).

69. **Specific Heat of Gases.** — This may be considered, (1) when the gas is kept in a close vessel, so that its volume cannot increase (specific heat under constant volume); (2) when the gas is allowed to expand freely (specific heat under constant pressure). The specific heat of gases does not vary with the temperature or with the pressure. When air is allowed to expand freely, about $\frac{5}{7}$ths of the heat applied is expended in producing elevation of temperature, the remaining $\frac{2}{7}$ths being employed in expanding the air, or in *work*. This is given out upon compressing the air. The heat evolved by suddenly compressing air is sufficient to ignite tinder.

70. **Relation between Specific Heat and Atomic Weight.** If instead of comparing *equal* weights of elementary bodies we take *atomic* weights (147), we shall find that their capacity for heat is equal, or nearly so. In other words, the specific heat of elementary bodies is inversely as their atomic weights. There are certain important exceptions to this law. This law also holds good in regard to compound bodies of similar chemical constitution, and containing the same number of atoms.

71. **Agency of Heat in Natural Phenomena.** — The change of season depends upon the fact that in summer the sun is longer above the horizon, and his rays are more nearly vertical (43). Climate is modified by the presence of large bodies of water, which render the temperature more uniform (65); by the gulf-stream, which conveys northward the warmer water of the tropics. The presence of snow-clad mountains, and of large forests which hide the earth from the sun's rays, render a climate colder.

The latitude, elevation, and prevailing winds also exert a marked influence. Winds, draughts, and currents depend upon the ascent of heated air, from the greater weight of a column of cooler air of equal height. The trade-winds and monsoons are periodical. The former are due to the ascent of heated air from the equator, and the inflow from the poles. They blow from the northeast and southeast; this obliquity being due to the rotation of the earth. The latter are caused by the alternate heating of the earth on opposite sides of the equator by the sun.

72. **Sea and Land-Breeze.** — When the sun shines on the sea and adjacent coast, the latter becomes raised in temperature, while the former remains nearly constant from its vast volume and great specific heat (68). Hence the cooler air from over the water gravitates and drives up the lighter warmer air over the land, giving rise to the sea-breeze. At night the land cools by radiation rapidly, while the sea maintains its uniform temperature, and a reverse current, the land-breeze, is produced.

Dew.—During the day the sun causes rapid evaporation of the surface moisture of the earth, which diffuses thro[illegible] the atmosphere; at night the earth cools by radiation [illegible] this moisture is condensed upon its surface just as in [illegible] mer it is seen on the surface of a vessel [illegible] Clouds prevent the formation of dew [illegible] radiant heat to the earth; winds carry [illegible] deposited. Clouds, fog, rain, snow, and [illegible] from the condensed moisture of the atm[illegible] conditions too complex to be fully dis[illegible] mentary work. See THE ATMOSPHERE ([illegible]

ELECTRICITY.

Is supposed to exist naturally in all bodies in a state of equilibrium, and to manifest itself when this is disturbed It is developed by *mechanical means* (statical or frictional electricity), by *chemical action* (dynamical electricity, galvanism, voltaic electricity), by *heat* (thermo-electricity), by *magnetism* (magneto-electricity), by *nervous force* (animal electricity). Magnetism being but a manifestation of electricitv, is conveniently considered first.

MAGNETISM.

73. **Magnets.** — Magnetic iron ore, Fe_3O_4, (loadstone,) possesses the property of attracting iron and certain other metals (nickel, cobalt, and perhaps manganese), and of communicating its powers to them; a bar of iron or steel thus magnetised is called an *artificial magnet.* Iron receives and loses magnetism readily, steel with difficulty.

A magnet is found to possess attractive powers principally at its ends, which are called its poles.

74. **Directive Tendency.**—If a magnet be suspended freely, it assumes a position nearly north and south. The end which invariably points north, is called the north pole, and *vice versa.* One pole cannot exist without the other; the fragments of a magnet each have poles. The north pole of a second magnet repels that of the first, and attracts its south pole, and *vice versa.* A magnet thus freely suspended forms a *compass-needle.* When two magnets are joined with the N. pole of one above the S. pole of the other, it constitutes an *astatic needle.*

75. **Induction.**—A piece of iron brought near a magnet has magnetic polarity *induced* in it, and is attracted; the

intensity of the attraction depends upon the distance, and is not interfered with by the interposition of neutral substances. This second magnet is capable of inducing magnetism in a third in a less degree, and so on.

76. **Variation and Dip.**—The line of direction of the magnet, called the magnetic meridian, varies from the true meridian. This deflection, which is not constant, is called the *variation* of the needle. A magnet free to move in a vertical plane will have a *dip*, which increases as we go from the equator towards the poles. The earth is supposed to be a great magnet, and the poles have been discovered, that is, points where the dipping needle was vertical, and the horizontal needle ceased to traverse.

77. **Diamagnetism.**—Researches with very powerful magnets (electro-magnets, 104) have shown that all bodies are probably more or less influenced by the magnet. Bodies which are attracted arrange themselves in a line joining the poles (*axially*), those which are repelled in a line at right angles to this (*equatorially*). The former are called *magnetics* or *paramagnetics*, the latter *diamagnetics*. Oxygen is highly magnetic.

STATICAL ELECTRICITY.

78. **Elementary Phenomena.**—If a tube or rod of dry glass be rubbed with a cat's fur, it will be found to attract light bodies, such as bits of paper. In the dark, a feeble bluish light is seen in the path of the rubber, and a crackling sound is heard; on presenting the knuckle, a slight spark will pass to it. Brought near the face, either the rod or rubber communicates a sensation as if cobwebs were in contact with the skin. A body thus affected is said to be *excited* or *electrified*. Electricity does not increase or diminish the weight of bodies under its influence. The

same phenomena may be observed (with proper precautions) in all bodies. Electricity readily passes from an excited body to a *neutral* one, and may be stored up for purposes of experiment.

79. **Two Kinds of Electricity.**—If a pith-ball be suspended by a silk string, it will be attracted by an excited glass rod. On touching the rod, it is repelled, but is then attracted by the rubber; or if touched by the finger, is *discharged,* and will then be attracted by either the rod or rubber. Similar phenomena in every respect are seen when the rod is composed of resinous matter or sulphur. A ball repelled by the glass will be attracted by the sulphur as by its own rubber, and *vice versa.*

80. **Hypotheses.**—Two hypotheses have been suggested to account for these and other electrical phenomena. Both involve the assumption of a subtile, ethereal, imponderable fluid pervading all nature, and existing in a state of quiescence or combination in bodies in their natural state. Franklin supposed that, when the electrical equilibrium was disturbed by friction, that one body received from the other a portion of this fluid, becoming *positive* +, while the other, having relatively less, was termed *negative* —. In case of glass, the rubber loses, while in that of resin the rod loses. Du Fay supposed the existence of two mutually attractive fluids, the *vitreous* and *resinous,* equal in amount but opposite in tendency; when associated together in equal quantity, they mutually neutralise. When disturbed, they are separated, one going to the rubber and the other to the body rubbed.

As neither hypothesis is probably true, that of Franklin is preferred from its simplicity. Either is competent to explain most of the phenomena.

Bodies similarly excited repel each other, and those of unlike excitement mutually attract.

81. **Conductors; Insulators.**—When a body is excited, the rate at which it will return to its normal condition depends upon the substances in contact with it. In dry air, the excitement will continue a long time; touched with a neutral rod of glass or resin, no sensible change is produced. In damp air, the excitement soon vanishes, and a touch of the finger or of a rod of metal instantly causes the discharge. Bodies which thus allow the electricity to pass through them are called *conductors;* those which do not, *insulators.* Bad conductors receive and part with electricity very slowly; if touched by an excited body, they receive electricity only at the point of contact, and if, when excited, they are touched, they lose electricity only at the point touched. Good conductors can only be excited when their communication with the earth is cut off. A metal rod shows no signs of electricity when rubbed, unless provided with a glass handle or otherwise insulated.

The following list will give a general idea of the position of the most important bodies as respects their conducting powers, beginning with the worst: Dry gases, gutta-percha, vulcanite, collodion, shellac, sulphur, amber, resins, silk, dry fur, glass, ice, volatile oils, fixed oils, vegetable fibres (string), animal bodies, water, saline solutions, flame, melted salts, charcoal, the metals. The relative conducting power of metals for electricity and for heat (47) is nearly the same. The most perfect insulators allow electrical influence to traverse them but by *induction* (85), not by conduction. The earth is the great common reservoir whence all electrical excitements proceed, and to which they all tend.

82. **Electroscopes** serve to indicate the presence of excitement by the divergence of light bodies similarly charged. One of the best is Bennett's, composed of two slips of gold leaf attached to the brass cap of a jar. On the approach or contact of an excited body, the leaves diverge. In order to determine the kind of excitement, it is only necessary to charge the instrument with electricity of known character. As opposite electricities attract, the

movement of the light bodies, will at once indicate that of the substance to be tested.

Electrometers measure the relative amounts of electrical force. It is found that the force of attraction and repulsion is directly as the amount of electricity, and inversely as the square of the distance of the bodies.

83. **Electrical Tension.**—The tendency of excited bodies to equilibrium is called their *tension*, and may be compared to a stretched spring. The equilibrium is restored, (1) By *conduction*. (2) By *disruptive discharge* (spark). (3) By *convection*, in which a body, as air, in contact with the excited object receives electricity, is repelled, and transmits it to a neutral body or one of opposite excitement. The velocity of electricity of high tension is as great as that of light, when of low tension it is much less. The duration of the electric spark is inconceivably short. It takes always the path of least resistance, which may not always be the shortest; hence the zigzag form sometimes seen. When electricity passes continuously, it is called a current.

84. **Distribution of Electricity.**—Electricity of high tension resides only on the outside surfaces of bodies; when of feeble tension, it may pass through the whole mass (as in a wire carrying a feeble current).

When the surface is a sphere, the electricity is uniformly distributed; on departing from this form, it tends to accumulate at the smaller portion, and will pass rapidly and quietly to and from points or sharp edges. The greater the surface over which a given quantity of electricity is distributed, the less its intensity.

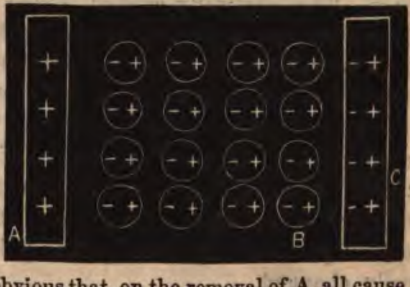
85. **Induction of Electricity.**—An excited body may disturb the equilibrium of a neutral one without contact, its influence being transmitted through the intervening insulator (*dialectric*). In this case the second body neither gains nor loses electricity, and returns to its normal

condition as soon as the excited body is removed. If, however, while excited it be touched, a portion of electricity of the same name as that of the excited body will pass to the earth, and the body will remain excited after the removal of the disturbing object, but with electricity of an opposite name. This action takes place by a *polarisation* of the particles of the intervening dialectric. The thinner the dialectric the more decided the induction. All insulators are not alike in the power of thus transmitting the excitement. A plate of shellac offers only one half as much resistance as one of air of equal thickness. The relative facility of induction of bodies compared with air as a standard, is called their *specific inductive capacity.*

If a positively excited rod be approached to the Bennett's electroscope (82), the leaves will diverge; the *cap* will be found to be negative, the lower ends of leaves positive. On withdrawing the rod, the leaves fall, and all excitement disappears. If, however, while the leaves are divergent, and the excited rod is near the instrument, the cap be touched with the finger, the leaves will fall, and all will be quiet. On *now* removing the rod, the leaves diverge, the cap will be found to be negative, and the lower ends of the leaves positive. If we had *touched* the rod to the cap, the whole would have been charged with positive electricity by contact.

The action of polarisation may be understood by the accompanying figure (12). Let A represent the positively excited body; the positive electricity of the particle, B, of air is repelled, leaving the side next the rod negative. This particle acts in a similar manner on C, and so on with diminished intensity through the chain; the last particle, C, acts upon the second body, driving the + electricity from the side B, and causing it to accumulate on C. It is obvious that, on the removal of A, all cause of excitement is withdrawn, and equilibrium is restored. On

Fig. 12.



touching C, however, a portion of + electricity passes to the earth, leaving A and B in opposite conditions, and attracting each other. This removes all signs of excitement. On taking away A, the negative electricity in B becomes manifest.

86. **Means of Accumulating Electricity.**—The electrophorus, electrical machine, and Leyden jar will be considered. The hydro-electric machine is not now used, and the induction coil will be described hereafter (108).

87. **The Electrophorus**, in its usual form, consists of a cake of resin and a metallic plate of nearly the same size, furnished with a glass handle. The resin is excited, and its upper surface becomes negative; the plate is laid on it, touched with the finger, and lifted. The negative electricity having escaped, it is charged positively by induction, and will give a spark. The disc of metal receives a *little* negative electricity by contact; but as it touches the resin in but a few points, and the latter is a bad conductor, the principal effect is by induction. This is a convenient instrument for the laboratory; jars may be charged by it, and gases exploded.

Messrs. Cornelius & Baker have introduced successfully a neat and portable form of electrophorus for lighting gas-burners.

88. **The Electrical Machine** consists of a plate or cylinder of glass, mounted on a shaft, and pressed by felt rubbers. The electricity excited by the friction is collected by points and conveyed to an insulated brass cylinder with rounded ends, called the prime conductor. The rubbers are attached to a similar *negative* conductor. As the electricity of the rubbers is imparted to the glass, more is supplied from the earth by means of a chain attached to them. A small quantity of an amalgam of zinc, tin, and mercury is applied to the rubbers. It greatly adds to the efficiency of the machine, probably by becoming chemically changed.

A cheap machine may be made by casting the plate of *red* *sulphur.* The skin of a cat, without amalgam, serves to excite it. Red sulphur is made by heating ordinary sulphur three times in an iron vessel to a temperature between 482° and 580° F., allowing it to cool thoroughly after each fusion.—(E. BECQUEREL.)

89. **The Leyden Jar** consists of a jar coated inside and out to within about three inches of the top with tin foil. A baked wood stopper is furnished with a rod having a chain at its lower end in contact with the inside of the jar, and a knob on its upper extremity. When the knob is approached to the prime conductor, a spark passes into the jar, and one of the same name will pass to a conductor placed near the outer coating. When charged, either the inner or outer coating may be touched separately with impunity, but on touching both, a shock is felt. If a jointed rod with a glass handle be used to make the communication, a vivid spark will be seen, accompanied by a snap. By connecting together a number of such jars, a large amount of electricity may be accumulated, and effects approaching those of lightning produced.

If the jar be insulated, but little electricity will pass into it, as the tension of the inner coating soon equals that of the prime conductor. If, however, the outer coating be in communication with the earth, the electricity received from the machine by the inner coating drives by induction an equal amount of the same name to the earth, leaving the outer coating negative. This attracts the + electricity so strongly that it cannot manifest itself by its action on any outside neutral body, and will not produce spark or shock (*latent* or *disguised* electricity). Still, the positive electricity is prevented from passing to the negative by the glass. If a communication be opened between the coatings, equilibrium is instantly restored. Owing to the resistance of the dialectric (85) the attraction of the + and — electricity is not quite sufficient to cause them to hold each other in a perfectly quiescent state, and a slight manifestation will be perceived on touching either coating; indeed, a jar may be discharged slowly by alternately touching the coatings. The thicker the glass, the more manifest is this condition of things. The electricity resides in the glass; the use of the coatings is merely to distribute it.

Effects of Electricity.—(1) PHYSICAL; (2) CHEMICAL; (3) PHYSIOLOGICAL.

90. (1) The **physical** effects of electricity of high tension are familiar. The disruption of solids, magnetisation of iron, fusion of wires, ignition of combustibles, result from thunder-stroke. Some of these physical effects are indirect, being due to the heat developed by the resistance of an imperfect conductor. Sparks are seen only in a resisting medium, as air; *in vacuo* there is simply an ovoidal tuft of light passing between the conductors resembling the *aurora borealis.* The colour of the spark depends upon the medium, being blue in nitrogen, crimson in hydrogen, and green in carbonic acid. A point giving off + electricity presents a distinct brush, a — point simply a small star.

91. (2) Many of the **chemical** actions of static electricity are indirect, such as the explosion of mixed gases (101). Among the direct effects may be mentioned the decomposition of water, of iodide of potassium, hydrochloric acid, ammonia, and nitrous oxide. The oxygen and nitrogen of the air unite under the influence of the electric spark, forming nitric acid, which is found in rain-water after thunder-storms.* Oxygen is converted into ozone (185).

92. (3) **Physiological.**—The shock of electricity is familiar to all, the spark from the prime conductor produces stinging and rupefaction. A person charged on an insulating stool feels a prickly heat and glow of the skin resulting in perspiration. Statical electricity is but little employed in medicine.

93. **Atmospheric Electricity.**—The electricity of the air is usually +, as may be shown by raising an insulated conductor upon a pole and connecting it with a delicate

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* It is possible that the nitric acid found in rain-water may be due to other causes.

electroscope. The earth is negative. Clouds, fogs, and rain disturb the electricity of the atmosphere in a marked manner.

Thunder-storms are more frequent in lower latitudes; beyond 70° they are unknown. They are generally confined to the lower strata of the atmosphere. In some localities, as California, they are very rare. A cloud charged with electricity induces an opposite condition in a second cloud, or on the earth. It is thus attracted (85), and when the distance is such that the tension of the electricity (83) can overcome the resistance of the atmosphere, a spark passes accompanied by thunder. This latter phenomenon is probably due to the noise produced by the rushing of the atmosphere into the space rendered rare by the passage of the spark. Lightning without thunder is due to clouds below the horizon, or in the highly rarefied upper regions of the atmosphere. When a cloud is of considerable extent, a flash passing to the earth is instantly followed by one in the opposite direction at its distant end (return stroke).

Precautions against Thunder-stroke.—Trees, from their height and comparatively good conducting power, attract lightning; so with rarefied air, as from barns and chimneys. These should be avoided. Gas and water pipes carry off electricity when it has fallen on a building, and thus often prevent serious damage. A metallic roof protects a building by diffusing the electricity over a large surface, diminishing its intensity proportionately, and allowing of its escape from the edges and corners of the metal.

Lightning-rods should be buried sufficiently deep to be always in moist earth or charcoal, or connected with a gas or water pipe. They are apt to rust off at the surface of the ground; a zinc ball or cylinder will protect from this for a long time (165). Copper is the best material, being about three times as good a conductor as iron, and less liable to corrode. The point is tipped with platinum, gold, or silver; the first is commonly used, but is apt to be defective from imperfect welding. Perhaps the best point is that of Dr. Hare, consisting of a solid copper point imbedded in a zinc ball, into which are also inserted pointed copper wires, forming a brush. The rod should be continuous and solid, as when electricity is being quietly carried off it is of low tension and passes through the body of the rod. Insulators are unnecessary. Large masses of metal in a building should be connected with the rod to avoid the *lateral stroke*.

Treatment after Thunder-stroke.—The patient should be stripped, freely affused with cold water, alternating with brisk frictions. Any subsequent symptoms to be treated *pro re nata*.

DYNAMICAL ELECTRICITY.

94. **Elementary Phenomena.**—If a plate of pure or amalgamated (97) zinc, and one of copper, be plunged into water acidulated with sulphuric acid, no action will be noticed. By delicate instruments it will be found that the lower portion of the zinc is positive, and that of the copper negative, while the portions above the liquid, or wires connected therewith, will be of an opposite polarity. By combining a large number of such cups, shocks may be felt, and feeble sparks seen. If now the plates be connected by a wire, or by touching their upper edges, all signs of electrical excitement cease, bubbles of hydrogen arise from the surface of the copper plate, while the zinc is gradually dissolved; no gas, however, is seen on its surface. The copper plate remains bright and uncorroded as long as any zinc is present. The connecting wire rises

in temperature, and is found to deflect the magnetic needle, and to cause magnetism in a rod of soft iron, if coiled around it. If the ends of the wire be tipped with platinum, and plunged into acidulated water, the latter is decomposed, oxygen arising at the end of the wire connected with the copper plate, and hydrogen from the other. The electricity passes from the zinc (positive) to the copper (negative) in the liquid, and from the copper to the zinc out of it, thus forming the simple voltaic circuit. The portions of the plates out of the liquid are termed *poles* or *electrodes*, and their polarity is the reverse of that of the plates, the positive pole being on the copper, and the negative pole on the zinc. The liquid is termed the *electrolyte*, and must be capable of conducting electricity, and of being decomposed by it.

The above experiment constitutes a single case of a very extended series of phenomena. We may have a single plate and two distinct fluids; we may reverse the direction of the current by reversing the chemical action. The general fact is, that all chemical action is attended by the development of an equivalent quantity of electricity; the course of the electricity being within the electrolyte from the body most acted on to the other.

95. **Theoretical Considerations.** — The explanation of the foregoing phenomena usually accepted may be briefly stated as follows, taking water as the electrolyte, and zinc and platinum as the plates. Zinc and oxygen tend to combine; hydrogen will not unite with zinc. When the plates are introduced, without touching, a polarisation (85) takes place, the atoms of oxygen turning towards the zinc, which at the same time becomes positive, while the platinum becomes negative by induction (Fig. 13). Upon making contact between the two metals, electrical equilibrium is instantly restored throughout the whole polar chain. At the same time the oxygen unites with

the zinc, forming a particle of oxide of zinc, ZnO, which unites with the acid; the hydrogen thus set free does not pass off, but unites with the oxygen of the next molecule; and so through the whole polar chain, the last+hydrogen is attracted by the negative platinum, but not being capable of combining with it, is set free (Fig. 14). This action is repeated until all the zinc is consumed. As the electrical equilibrium is restored as fast as it is disturbed, it is obvious that in such an arrangement no evidences of electrical *tension* (83) can be observed. It may be compared to an ordinary electrical machine, in which the prime conductor and rubber are connected by a wire. The same amount of electricity is developed by turning the plate as when the prime conductor is insulated, but equilibrium being instantly restored, no sparks or shocks can be perceived.

Fig. 13.

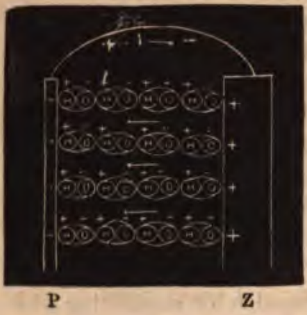
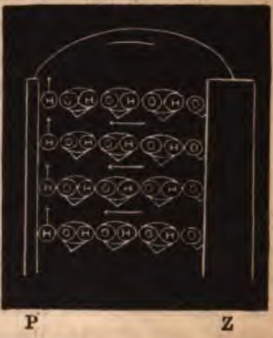


Fig. 14.



The above explanation is imperfect in some respects, and physicians are not yet decided upon the theory of the voltaic circuit. Faraday regards the chemical change as the cause, Schönbein as the effect of the action.

96. **Quantity and Intensity.**—These terms are much

employed in speaking of voltaic arrangements and phenomena, yet it is difficult at first to get a clear idea of their meaning. An illustration drawn from the subject of heat may aid the student. A grain of platinum wire heated to intense whiteness, if plunged into a pint of water at 40° F., would only raise its temperature about $\frac{1}{10}$ of a degree; its *quantity* of heat is therefore small, while its *intensity* is great. Ten pints of warm water, in which the hand may be comfortably immersed, would raise the same to about 94° F., or 54°; yet, although the quantity of heat is relatively much greater, its intensity is less, and by no known means can we convert heat of low into that of high intensity.

Electricity of small quantity and great tension gives sparks and shocks, and can overleap obstacles. Electricity of quantity and low intensity develops much heat, magnetises powerfully, and causes a proportionately greater amount of chemical decomposition. The former is characteristic of the machine electricity, the latter of the voltaic or current electricity. The method of arranging voltaic cells in order to attain the maximum effect will be considered hereafter (99).

Faraday and Becquerel have shown by actual experiment that the quantity of electricity developed during the decomposition of a single drop of water equals that of a coated surface of Leyden jar of 32 acres, or that of a powerful flash of lightning; yet so feeble is its intensity, that it could not pass through a film of air the $\frac{1}{1000}$ of an inch in thickness.

97. **Resistances and Defects.**—These may be stated as (1) Imperfect conduction, (2) Adhesion of hydrogen to the negative plate, (3) Local action.

(1) **Imperfect Conduction.**—The electrolyte opposes resistance depending on its nature, and increasing with the distance between the plates. The plates themselves are imperfect conductors, and so are the connecting wires;

the resistance of a wire being directly as its length, and inversely as the area of its cross section. We should therefore use thick plates, place them as near together as possible, and make the connections with short and thick copper wires or ribbands.

(2) **Adhesion of Hydrogen.**—In the arrangement before described the hydrogen arising from the negative plate adheres in bubbles, and thus cuts off a large portion of its surface; the gas also acts by reason of its *electro-positive* character (164) to diminish the difference of electrical condition of the two plates upon which the voltaic action depends. It adheres less to *rough* surfaces, and may be chemically consumed or burned (98).

(3) **Local Action.**—Commercial zinc contains other metals, as lead, tin, cadmium, also carbon. These act as small negative plates, causing circuits to be set up on the surface of the zinc, eating it into holes, and injuring the action of the cell. It is prevented by *amalgamation;* the zinc is washed with dilute sulphuric acid, and plunged into mercury—the deeper the better,—or mercury is rubbed over it. The action of the mercury is not clearly understood.

98. **Forms of Voltaic Cells.**—*Volta's original pile* consisted of discs of copper, zinc, and cloth moistened with dilute acid or a solution of common salt; the arrangement being copper, cloth, zinc. A sufficient number of these were arranged in a pile or column, the terminal zinc and copper provided with wires, and the whole insulated. The electroscope shows the zinc end to be positive, and the copper negative. On touching the ends, a slight shock is felt, and a spark is seen on *breaking* contact of the wires. The wires immersed in acidulated water cause its decomposition. The pile has been compared to a Leyden jar, capable of recharging itself indefinitely. This apparatus

is interesting, as showing the identity of frictional and voltaic electricity.

(1) **Single Fluid Batteries.**—Various forms have been employed; the principle being, however, the same in all. Plates of zinc and copper are alternately connected, and to the terminal plates wires are attached; the plates are immersed in dilute sulphuric acid, or other electrolyte. One of the most convenient, where many plates are used, is that of *Dr. Hare*, where two troughs are arranged at right angles; in one are the plates, in the other the acid; by turning a crank attached to a shaft supporting the troughs, the liquid is thrown off or on the plates. They are not now often employed. *Smee's cell* consists of two zinc plates, and between them, but insulated by baked wood, is a plate of silver coated with finely divided platinum, to roughen it. Dilute sulphuric acid, 1 part to 10 of water, is used as the electrolyte. The roughness of the negative plate prevents to a great extent the adhesion of the hydrogen. It is a convenient arrangement, much used in electro-plating, telegraphs, and for exciting the induction coils known as electro-magnetic machines. In the *sulphate of copper* cell a solution of blue vitriol is used as the exciting fluid. No hydrogen escapes from the negative plate, as it is consumed by the oxygen of the oxide of copper, sulphuric acid being set free to act upon the zinc, and metallic copper deposited on the negative plate. The reaction may be thus expressed: $Zn+CuO,SO_3+nHO=ZnO,SO_3+nHO+Cu$. This form is rarely used, as the copper deposits on the zinc on account of local action, and the sulphate of zinc formed is decomposed by the current, and zinc is deposited upon the copper. If employed, both plates should be well scrubbed after each immersion.

(2) **Double Fluid Batteries.**—These have a different liquid for the positive and for the negative plate, the two being

separated by a porous cell, which allows of the transmission of the electrical effect, but prevents to any considerable extent the admixture of the liquids. *Daniell's Constant Battery* consists of plates, generally concentric cylinders, of zinc and *copper*. Next to the copper is a saturated solution of sulphate of copper, then a porous cell, and in contact with the zinc, dilute sulphuric acid. The action is essentially the same as in the cell last described, but the porous cell prevents the contact of the copper solution with the zinc, and thus avoids the deposition of that metal on the positive plate, and *vice versa*. The reaction may be expressed thus: $CuO,SO_3+HO,SO_3+Zn=ZnO,SO_3+HO,SO_3+Cu$. The sulphuric acid set free during the reaction, passes through the porous cell and maintains a uniform chemical action on the zinc. This battery is *constant* for days, and is largely used where great intensity is not required. The liquids however will gradually mix by *osmose* (132), rendering it necessary after a time to clean the zinc plate. *Grove's* consists of a zinc and *platinum* plate separated by a porous cell; the zinc is excited by dilute sulphuric acid; next to the platinum is concentrated nitric acid. The hydrogen is consumed by the oxygen of the nitric acid at the surface of the negative plate. The reaction may be given as $Zn+HO,SO_3+HO,NO_5=ZnO,SO_3+2HO+NO_4$. The force of a Voltaic circuit is *cæteris paribus* equal to the amount of chemical action at the surface of the positive plate, less that necessary to effect the decompositions. The last atom of oxygen of nitric acid is loosely combined and readily unites with the hydrogen of the electrolyte. Nitric acid batteries are therefore the most intense known.

In *Bunsen's cell* dense *carbon* is substituted for platinum; these are much cheaper than the last, but more troublesome and less intense. A solution of bichromate of potassa 1 lb., sulphuric acid 2½ lbs., and water 1 gall., is advantageously substituted for nitric acid in Bunsen's battery, no fumes being given off. Chromic acid is liberated and yields its oxygen to burn the hydrogen, depositing green sesquioxide of chromium Cr_2O_3. In the *Maynooth* battery *iron* replaces platinum, becoming *passive* in strong nitric acid. This is a cheap and intense combination, but troublesome to manage.

99. **Combination of Cells. Electro-motive Force.**—Properly speaking, the term *battery* is applied to a collection of cells or elements united. It is frequently used to signify a form of cell. It must be borne in mind that the chemical and electrical effects in any voltaic circuit are equivalent and mutually dependent; whatever retards one diminishes the other. The greater the resistance to the passage of electricity, the less the amount of chemical action, and the less the *quantity* of electricity developed. Therefore by diminishing resistance, or by increasing *intensity*, the quantity of electricity from a given positive surface will be proportionately increased. To increase intensity, a number of cells are employed, the zinc of one connected with the copper of the next, as in Volta's pile. Here each cell gives a new impulse to the current; but as the quantity developed depends upon the size of the plate or the number of polar chains (95), increasing the number of cells in this way only indirectly increases the quantity developed by augmenting intensity, and thus overcoming resistances. This combination of quantity and intensity is termed *electro-motive force.* The maximum effect is found to be produced (Ohm's law) when the resistance in the closing arc and that in the battery are equal.

The product of quantity by intensity is a constant. If we had a pair of plates of 100 square inches of surface, we might designate the quantity by 100 and the intensity by 1. If we cut this into one hundred plates of 1 inch square, and connect them alternately, copper and zinc, the quantity is but $\frac{1}{100}$ of its former amount, or 1, while the intensity is 100. It is obvious that by connecting all the zinc plates together, and similarly all the coppers, we have the same effect as in the two original plates.

Again, suppose we had two large plates, say of 1000 square inches each, if we had to pass the current around a piece of soft iron by means of a short thick wire, we should probably attain the maximum magnetic effect by using the two single large plates, as here quantity, not intensity, is required. If we plunge the wires of such a cell into acidulated water, no decomposition will take place; there is not intensity enough to traverse the electrolyte; cut each plate into two of 500 square inches, and join them consecutively, decomposition will begin, but by cutting each into four of 250 square inches, we should probably get the maximum effect. Although the amount of water decomposed depends upon the *quantity* of electricity passing, we have gained by diminishing surface to one-fourth, in order to quadruple *intensity*.

100. **Effects of Voltaic Electricity.**—1. Physical; 2. Chemical; 3. Physiological.—1. Physical. *Deflagration.* When electricity is resisted, it develops heat. The amount of heat developed is directly as the resistance, multiplied by the square of the intensity of the current.* By passing a powerful current through thin metallic wires, they are heated, fused, or burned. This fact is applied to submarine blasting, etc. When the current passes between carbon poles which are touched and then separated, an arch of flame passes, the carbon becomes white-hot, is softened, and carried over from the positive to the negative pole. The light is intense (electric light), and the heat the highest attainable by artificial means. The phenomena are observed in vacuo or in a neutral gas.

101. **Electro-Magnetism.**—If a current be transmitted from north to south above a compass-needle, or from south to north below it, the north pole will deflect to the east, and remain in a position due to the combined deflecting power of the current and directive tendency of the earth's magnetism. If the direction of the current be reversed, the deflection will also be reversed. By increasing the

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* De la Rive, *Traité d'Electricité*, t. II., p. 177

number of turns of the wire around the needle, the effect is correspondingly increased, less the retardation of the current due to the increased length of wire. By using an astatic needle (74), one bar being placed within the coil and one above it, a very delicate index of the direction and the force of currents is obtained. This is called the *Galvanometer.* The poles of the magnet, moreover, tend to revolve around the wire, but in opposite directions; no such rotation is seen, therefore, unless the current is allowed to affect but one pole at a time. When the current passes in the direction from the face to the back of a watch, the north pole will rotate in the direction of the hands (*right-handed rotation*), and *vice versa.* If the wire be free to move and the magnet stationary, the wire will revolve.

102. **Ampère's Theory.** — Ampère supposed that in a permanent magnet each particle might be considered as surrounded by a constantly circulating current of electricity; the effect would be the same as of that of all these currents united, and passing around the magnet; the direction of the current is right-handed when we look at the south pole. Wires carrying parallel currents in the same directions mutually attract; when the currents are in opposite directions they repel. Wires carrying currents in the same direction, but not parallel, tend to become so. These facts may be shown by experiment. A consideration of the foregoing will render clear the whole phenomena of electro-magnetism.

Fig. 15 represents a model devised by the author for rendering clear these somewhat difficult points. N S represents a permanent magnet; A, a disc of tin with an arrow cut out of it, represents the direction of Ampère's supposed current, and will serve to show the difference between the right- and left-handed rotation and the opposite polarity of the front and back of a current (103). A wire, B, supposed to carry a current, passes from N to S above the needle, and S to N below it; it will be seen at once that when the N. pole of the needle turns to the east, the two currents are parallel. (Fig. 16.)

Fig. 15.

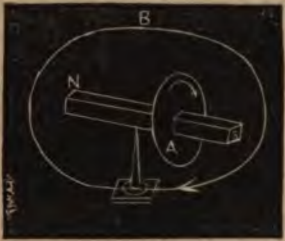
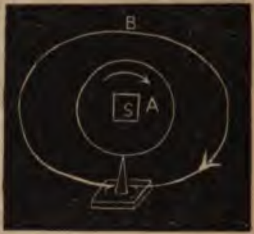


Fig. 16.



103. **Circular Currents Magnetic.**—If a piece of wire be bent into a circle, or, better, coiled into a *helix* (like a corkscrew), and have soldered to its ends a small plate of zinc and one of copper, and be floated on the surface of acidulated water, it will be found to arrange itself in the magnetic meridian, and to be attracted and repelled by the magnet (*De la Rive's* ring). In any case, if the current be circulating in the direction of the hands of a watch, the north pole will be towards the back of the watch, and *vice versa.* Hence one side of the wire has N., and the other S. polarity.

Roget's Oscillating Helix shows this fact in a striking manner. A helix of tolerably fine wire is fastened to a support, and connected with one pole of a battery; the other pole is in contact with a cup of mercury, into which the lower end of the helix dips. This completes the circuit. As the upper and lower sides of the coils of the helix have opposite polarity, they mutually attract. This shortens the helix, and the point is raised out of the mercury. The current is thus interrupted, the magnetic polarity ceases, and the point of the wire falls again into the mercury. A constant oscillation is thus maintained. The introduction of a permanent magnet causes a more rapid contraction.

104. **Electro-Magnets.**—By coiling wire around soft iron, powerful temporary magnets may be produced. The

magnetism continues so long as the current continues to flow, and ceases when it is interrupted. Magnets on this principle have been made to support a ton, and to show that all bodies are more or less influenced by the magnet (77).

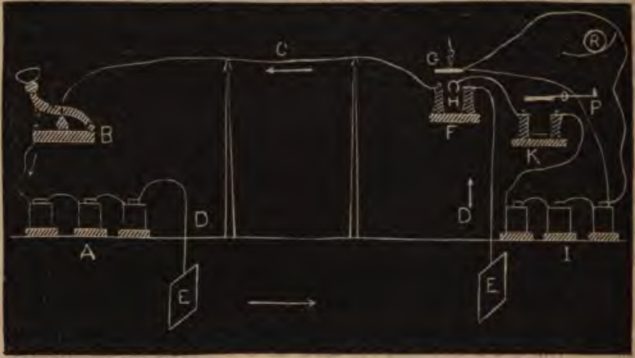
When the quantity of electricity is more than sufficient, the magnetism of the bar does not cease upon its interruption, but the armature adheres with a slight force. If, however, a thin piece of brass or paper be placed between the magnet and armature, no such *residual magnetism* is noticed. It instantly ceases when the keeper is forcibly removed, after breaking the circuit. If a considerable length of wire be coiled so as to form a thick helix, a bar of soft iron will be drawn up into its centre or core, and there remain suspended without any apparent means of support. (*Axial Magnetism.*)

105. **Applications of Electro-Magnets.** — *Engines* have been constructed to be moved by electricity. Apart from other considerations, the cost of the zinc necessary to produce a certain mechanical effect, compared with ordinary fuel, forbids the expectation of their useful employment.

Magnetic Telegraphs. — As there is no practical limit to the distance to which electricity may be transmitted through a good conductor, and as a current of electricity will induce magnetism in a core of soft iron which may be discharged at pleasure, it is obvious that we can, by causing the armature of the magnet to make signals, communicate through indefinite distances. To make and break the circuit with ease, a key is used by which two ends of the wire are pressed together easily. As the current becomes very feeble from the resistance of the long conducting wire, a *relay* or receiving magnet is used. In this the current from the distant station passes around a delicate electro-magnet, the armature of which is allowed the least possible quantity of play. This acts as the key to a *local* battery close at hand, which works the recording apparatus. The signals may be arbitrary, by strokes of a bell, or by a mural alphabet of dots, dashes, and spaces (Morse), or by exceedingly ingenious arrangements the message may be printed (House, Hughes), or even sent autographically (Chemical Telegraph). It is impossible to enter into details here.

The following sketch will serve to give the student a rough idea of the arrangement of a line of Morse telegraph. In practice, the current is continually passing through the main line, and is broken to make the signals:

Fig. 17.



A, main line battery; B, signal key; C, main line wire; D, ground wires; E, ground plates; F, relay; G, its armature; H, one end of wire of local circuit, the other being attached to the armature of the relay magnet;—when the armature is drawn to the magnet, these ends are brought in contact, and the *local* circuit is completed;—I, local battery; K, recording magnet, which, when the current passes, draws its armature, L, which presses the point, P, against a fillet of paper passing over the roller, R. The recording apparatus is not necessary. A good operator will be able to read the Morse alphabet by the sound of the clicking of the relay. A single wire only is employed, the circuit being completed through the earth by means of the ground plates.

Magnetometers.—As the quantity of magnetism developed is proportionate to that of the electricity passing (up to the point of saturation), electro-magnets are used to measure currents of considerable power by noticing the weight necessary to detach the armature.

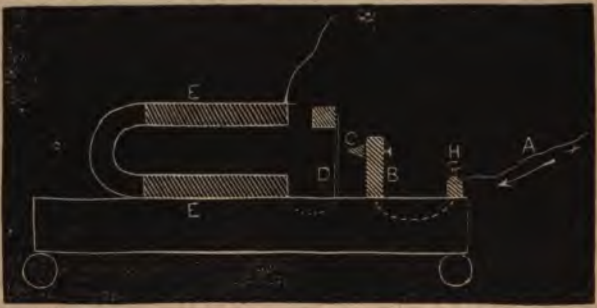
106. **Induced Currents.**—If a tolerably long wire be connected with a cell or battery, no spark will be seen on making the connection; but on breaking it, a vivid spark will be visible, which will be greater in proportion to the length of the wire and the power of the cell, up to a certain point; at the same time a slight shock will be felt. This is the *extra current* of Faraday, and probably depends upon the disturbance of the normal electricity of the wire by the current of low intensity passing through it. Its direction is opposite to that of the battery or *primary* current. The two may be separated by coiling the wire from the battery (primary wire) and placing a second similar coil (secondary coil) parallel to it, but insulated from it; (ribbands are better than wires.) On making contact with the battery, a feeble shock is felt on grasping the ends of the secondary wire, but on breaking it the shock is marked and sparks may be obtained. In this case but little extra current is noticed in the primary wire. By continuing the experiment, currents of decreasing intensity may be induced in a third, fourth, and as far as a ninth coil or spiral; in every case the current induced is momentary, and in a direction opposite to that of the inducing one. We have thus a means of obtaining electricity of tension by means of the voltaic current.

107. **Electro-Magnetic Machines.**—Under this name induction coils are sold and much used in medicine. Their construction is simple. Around a spool is wound a short coarse wire wrapped with silk, to insulate its turns. Outside of this is wound a long fine wire similarly wrapped. The inner (primary) wire is connected with the cell; to the outer one are attached convenient handles for communicating the shock. The circuit in the primary wire is

broken by any suitable means, as by drawing it over a rasp, or by the automatic break described below. On each contact and break a current is induced in the secondary wire; that produced on the break being much more intense. These *to* and *fro* currents are felt upon grasping the handles. A bundle of soft iron wires introduced into the primary coils increases the shock by becoming magnetic (electro-magnetism [111]); by withdrawing them gradually, the shocks may be reduced.

It may be well for the student clearly to understand the automatic break-piece attached to the apparatus usually sold, as it often requires adjustment.

Fig. 18.



The wire, A, Fig. 18, from the battery is fastened to a binding screw, H, whence a wire passes to the metallic post, B, which has on it a point, C, tipped with platinum. This rests against a platinum spring, D, which carries at its top a piece of soft iron. From the lower part of the spring the primary wire passes around the small electro-magnet, E, and thence to its coil and back to the battery. On making connection, the current passes through the post B, spring A, and around the electro-magnet E. This then attracts its keeper, and draws the spring away from the point C. The circuit is thus broken, the spring flies back and instantly renews it. This takes place many times in a second, producing a peculiar humming. The point C is adjustable by means of a screw.

108. **The Ruhmkorff Coil** is simply a large apparatus, similar to the one described. The external wire in one recently made by Ritchie is forty miles long. It is provided with a large surface of tin foil packed in the base, to distribute and weaken the *extra current* (106). The electricity flows in but one direction, as the induced current set up on *making* the primary connection is too feeble to travel the whole length of the outer coil. By means of this apparatus sparks of eighteen inches in length may be obtained in rapid succession, and all the phenomena of statical electricity shown with a splendour before unknown.

Although the name of Ruhmkorff is attached to this apparatus, the credit belongs mostly to others. Prof. Henry investigated the phenomena of induced currents. Faraday invented the concentric coils; De la Rive the automatic break-circuit; Fizeau the condenser. In Ruhmkorff's original coil he obtained a spark of one inch. After Fizeau's improvement, Hearder, by more careful insulation, reached three inches. Mr. E. S. Ritchie, of Boston, by a new method of winding and insulation, arrived at the eighteen-inch spark above mentioned.

109. **Chemical Effects of the Voltaic Current.** — These will be considered under the head of CHEMICAL DECOMPOSITION (162).

110. **Physiological Effects.** — These vary with the strength and direction of the current and the mode of its application. A moderate current produces contractions, when sent in the direction of the distribution of a nerve of general sense, and pain, and sometimes paralysis when reversed. The phenomena are noticed only upon making and breaking the circuit, but it is by no means certain that the influence of the current is not exerted during the whole time of its flow. Nerves of special sense, except the olfactory, are excited so as to give rise to the sensations proper to them. The muscles may be excited by passing currents of considerable intensity across them, independent

of the direction of the nerve fibres; and when the nerves are paralysed, the muscles sometimes still contract under such influence. The secreting organs and absorbents are stimulated by electricity; the blood is coagulated around the positive, and rendered more fluid around the negative pole. Chemical substances can probably be introduced into the system or removed from it by the same agent. For the medical applications of electricity, see (117).

MAGNETO-ELECTRICITY.

111. As a current will induce magnetism; so, reciprocally, a magnet will induce an equivalent amount of electricity. If we introduce into a coil of wire the pole of a permanent magnet, a galvanometer will show the presence of a *momentary* current in the wire, the direction depending upon the name of the pole introduced.

112. **Magneto-electric Machines.** — Opposite the poles of a powerful horse-shoe magnet are placed two soft iron armatures, wrapped with insulated wire; they are so arranged as to be rapidly rotated by means of a multiplying wheel. The keepers become magnetic by induction, the electricity induced by them in the wires is conveyed to handles, and may give rise to sparks, shocks, and decompositions. The currents being *to* and *fro*, are thrown into the same direction by means of a *commutator* or *pole changer*.

As powerful magnets are produced by comparatively feeble currents, so they are required to give satisfactory results in the apparatus above named.* As no batteries are required, and the rotation may be performed by machinery, attempts have been made to use magneto-electricity in telegraphs, electro-plating, and electric light, but with partial success. For medical use the absence of an exciting cell certainly constitutes an advantage, counterbalanced however by the comparatively feeble current, and the labour required to produce the rotation.

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* By using the magneto-electric current, as the primary, to excite a powerful electro-magnet, and using this again as a source of electricity, Mr. Wilde has obtained an electric arch having three times the actinic power of the sun. It is manifest that the mechanical force required to turn the machine is here converted into electricity.—*Chem. News*, Nos. 338, 339.

THERMO-ELECTRICITY.

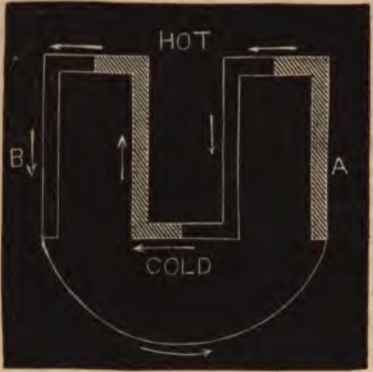
113. As any obstruction to the passage of electricity develops heat, so an obstruction to the passage of heat in a conducting circuit develops electricity. If an homogeneous, straight, short wire be connected with a sensitive galvanometer, and heated, no evidence of electrical current will be obtained. If, however, it be bent or twisted, its molecular tension at that point is altered, and on heating it the needle will be deflected.

If two dissimilar metals be joined, and the junction heated, electricity will pass. This phenomenon is most manifest in metals of a highly crystalline structure, and which are poor conductors. The order of the metals in the thermo-electric series bear no relation to their position in the voltaic pile, nor can it be certainly connected with their properties as regards heat or other force. The following is a list of some of the most important, beginning with the most positive: Bismuth, platinum, lead, tin, copper, gold, silver, zinc, iron, antimony. The alloy German silver is highly positive. The thermo-electric position of alloys is not a mean of that of their constituents.

114. **Thermo-Multiplier.**—By arranging a large number of bars in a pile, heating one series of junctions, and keeping the others cool, a battery may be formed capable of magnetising large bars; by connecting a similar arrangement with a galvanometer (101), we have a means of measuring temperature far more delicate than any thermometer.

The method of arranging the bars can be understood from the adjoining figure. The bars are kept separate by non-conducting material. The instrument made by Mr. Weygant for the Philadelphia High School, will show the heat from the face of an observer at the distance of eight feet,* and distinctly that of a fly crawling over the pile.

Fig. 19.



M. Marcus† has proposed a pile of alloys, the positive being, copper 10, zinc 6, nickel 6; the negative, antimony 12, zinc 5, bismuth 1. This will bear a high temperature, and all the effects of the ordinary voltaic combination may be obtained.

115. **Heat and Cold by Electricity.**—By passing a current of low intensity through the connecting wire, one end of the pile becomes heated and the other cooled; the amount of difference of temperature being equivalent to that required to produce a corresponding current, making allowance for the heat developed by the resistance of the conductors.

Electricity of Crystals, etc.— Certain crystals when heated develop electricity, one extremity becoming the other. On clearing crystals of mica, breaking metals, as zinc, or other bodies, as sugar, light is seen and electricity manifested. In fact, it may be stated that no molecular change can take place in matter unattended by electrical disturbance.

116. **Animal Electricity.**—1. STATICAL.—Certain fishes, as the *electrical ray* and the *Surinam eel*, have the power of giving electrical shocks at will. The electricity being

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[*] *Journal Franklin Institute*, Aug., 1855.

[†] *Chem. News*, No. 286.

collected by the condenser and Leyden jar, is found to exhibit all the phenomena of that derived from ordinary physical sources. The two extremities or sides of the animal are of opposite polarity; the head of the eel and the top of the torpedo being positive. The electricity of the eel is more intense than that of the torpedo. After repeated discharges, the fish becomes exhausted and harmless until allowed rest and food. The electrical organ consists of a series of small membranous tubes, which in the torpedo are arranged perpendicularly to the back, and in the eel longitudinally. These tubes are packed regularly together, forming hexagonal columns. Each of the tubes is minutely subdivided by membranous diaphragms forming cells which contain a mucous fluid; these again are traversed by a fringe of nerve filaments coming from the 8th pair. If communication with the brain be cut off, no electricity is developed.

2. DYNAMICAL.—The existence of voltaic currents in the animal body has been demonstrated by numerous experiments. Matteucci constructed a pile of muscles of recently killed frogs and pigeons by which he was enabled to deflect the galvanometer as much as 40°, and to decompose iodide of potassium.* The following are some of the more important facts. 1. The poles of a galvanometer applied to different surfaces give evidence of the passage of a current, as between the skin and mucous membranes. 2. There are normal electrical currents existing in muscles and nerves which are temporarily diminished upon the contraction of the former or the sudden action of the latter. 3. All the organs of the body exhibit electrical currents when they have been divided and the normal surface and the surface of the section are brought into contact. The direction of the current in nerves and

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* DE LA RIVE, *Traité d'Electricité*, tome III. p. 12.

muscles is from without to within. The electro-motive power lasts after death as long as the excitability of the nervous and muscular fibres.

117. **Medical Applications of Electricity.**—These are becoming more numerous as the subject is better understood. Among the cases in which it has been successfully applied may be mentioned, paralysis, rheumatism, indurations, certain tumours, constipation, eruptions of the skin, amenorrhœa, aneurism, and suspended animation. There is considerable diversity in the methods of application, and some discordance in the testimony as to their relative value. The following are the most important: 1. The direct current, which may be continuous, as in the case of aneurism; or interrupted, as generally used. Complete interruption is not necessary, as by altering the pressure on the electrodes a variation in the intensity of the current is produced—the *wavy* or *labile* current. Any of the voltaic cells heretofore described may be used. Pulvermacher's chain consists of a number of zinc and brass wires, so arranged as to form, when dipped in vinegar, a flexible voltaic pile of some intensity. It is rarely used. The interruption may be by hand, by clock-work, or, as in Smith's apparatus, automatic. 2. The *extra* current (106) has more intensity than the primary current, and is definite in its direction. It is given by the machines of Duchène, Kidder, Chester, Hall, etc. 3. The secondary or induced current, obtained from the induction coil (127), or magneto-electric machine. The former is *to and fro*, the latter definite in direction. These are the most intense currents, and those most generally used. They are sometimes termed *faradaic* currents, and their application *faradisation*. For the details of the methods of applying these currents in various cases, the student is referred to the works on medical electricity.

CORRELATION AND CONSERVATION OF FORCE.

118. As there is no destruction of matter, nor is it now created, so force is never lost, nor does it now originate. The universe gives us no example of rest, and there is reason to believe that even the molecules of matter, when apparently at rest, are in a constant state of motion or vibration, and that these vibrations give us the various phenomena of the physical forces. We may include the modifications of force under the heads of gravitation, light, heat, electricity, magnetism, chemical affinity, and vital force. How these are connected will be evident from a few examples.

Gravitation produces motion, as in falling bodies. Motion, when arrested, develops heat (friction, percussion), or electricity (90). It also promotes chemical affinity, as in the synthesis of alcohol (144); and decomposition, as in the explosion of chloride of nitrogen. It may be produced by heat (expansion, etc.), electricity (pith-balls), magnetism (magnetic toys), chemical affinity (indirectly), and the vital force. The fact that heat and motion are mathematically equivalent has been shown (35).

Light produces chemical change (the growth of trees), and perhaps magnetism.

Heat produces motion, light, electricity, and it affects magnetism. Magnetism is destroyed by a red heat, and bars may be magnetised by heating to redness and suddenly cooling them while they are in the plane of the magnetic meridian. Heat causes chemical combination (mixed oxygen and hydrogen), and decomposition (gunpowder). It is essential to animal and vegetable existence.

Electricity produces motion, light, heat, magnetism, and causes various physiological phenomena.

Magnetism develops motion and electricity (by the aid of motion), and thus indirectly the other phenomena.

Chemical affinity develops electricity (galvanism), light, heat (deflagrations), and indirectly motion. It is the source of vital heat, and probably of all vital function.

The vital force (if it be a distinct force) develops directly and indirectly the others named. It is due to chemical change constantly going on in the organism. In drawing a match, the vital force produces motion, which, being resisted by friction, is converted into heat, which develops the affinity between the combustible of the match and the oxygen of the air. Combination ensues; the match burns; heat is developed by the combination, light by the heat, and electricity and magnetism might be produced by the agency of a thermo-pile.

PART II.

PRINCIPLES OF CHEMISTRY.

MOLECULAR FORCES

Are those which act only at insensible distances; they may be divided into:—

I. Cohesion, the attraction of the particles of the same body.

II. Adhesion, the attraction of the particles of different bodies without change of properties.

III. Chemical Affinity, the attraction of the particles of different bodies with the loss of their *specific identity.*

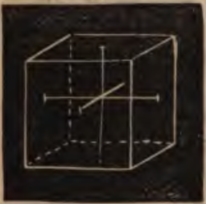
I. COHESION

119. Is believed to be but a modification of the great force of universal gravitation (9). It is strongest in solids, and imperceptible in gases. It is opposed by heat (49), and may be overcome by mechanical force. It may produce motion, as in the projection of an arrow from a bent bow. To variations of cohesion are due the properties of hardness, softness, malleability, ductility, tenacity, brittleness, elasticity, etc. The nature of these variations, and the causes of the differences of the above qualities in various bodies, or in the same body under different conditions, are wholly unknown to us.

Hardness has no relation to *density;* soft steel changes but little, if any, in density, by being hardened. Steel is hardened by being heated and then suddenly cooled; it is tempered by reheating and slow cooling; the temper is *drawn down*, that is, the steel is softened more, as the temperature of the reheating is higher. Copper is hardened by slow cooling, and tempered by a sudden chill. *Elasticity* is the tendency of a body to resume its original form or volume; there is no perfectly elastic solid body; air and permanent gases are absolutely elastic. *Tenacity* is most marked in bodies that are not crystalline (amorphous). Glass suddenly cooled will fly to pieces explosively on its surface being scratched or broken. (Bologna phials; Prince Rupert's drops.)

120. **Crystallisation** (Gr. *krystallos*, ice). When the force of cohesion causes the particles of bodies to arrange themselves when solid in certain definite geometrical forms, the process is termed crystallisation. Although the varieties of crystals are apparently infinite, yet all may be included in six systems, according to the number, length, and inclination of their axes. The axes are imaginary straight lines connecting opposite sides, edges, or angles of the crystals.

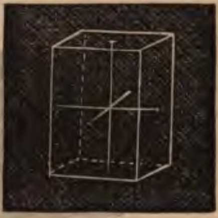
Fig. 20.



In the *first* system, *monometric* (Gr. *monos*, one, *metron*, measure), the axes are all equal and at right angles. The fundamental form is a *cube*, Fig. 20, and from it may be derived the *regular octohedron* (eight-sided figure), which is bounded by equilateral triangles; the *rhombic dodocahedron*, having twelve equal rhombic sides; the *tetrahedron*, having four equilateral triangles, one as a base, and three as sides; with many others. The following bodies are found in this system: most metals, diamond, galena, white iron pyrites, common salt, sal-ammoniac.

In the *second* system, *dimetric* (*dis*, twofold, *metron*, measure), the axes are at right angles, but only two are equal. The fundamental form is a *right square prism;* Fig. 21; that is, a column having a square base, a varying height, and standing upright. From it may be derived the corresponding octohedron and other forms. The following among others crystallise in this system: calomel, ferrocyanide of potassium, oxide of tin, cyanide of mercury.

Fig. 21.



In the *third* system, *trimetric* (*tris*, threefold, *metron*, measure), the axes are at right angles and all unequal. The fundamental form is a *right rectangular* or *right rhombic* prism, having a rectangle or rhombus for a base, and standing upright; Figs. 22 and 23. The sulphates of magnesia, zinc, lead, and baryta; nitre, sulphur (from solution) crystallise in this system.

Fig. 22.

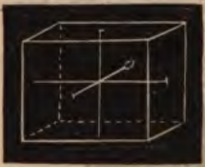


Fig. 23.

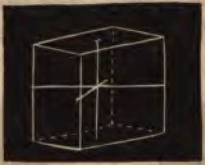
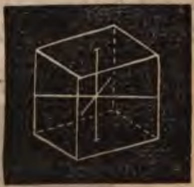


Fig. 24.



In the *fourth* system, *monoclinic* (*monos*, one, *clino*, I incline), one of the axes is oblique to the other two. The fundamental forms are a *right rhomboidal* or *oblique rhombic* prism; Figs. 24 and 25. In the former, the base is a rhomboid, in the latter a rhombus; the former is upright, the latter inclines. In the former the oblique axis is in the base, in the latter in the elevation. Borax, sulphates of soda, lime, and iron and sulphur (from fusion) are examples.

In the *fifth* system, *triclinic* (*tris*, threefold, *clino*, I incline), none of the axes are at right angles. The fundamental form is a prism having a rhomboidal base and inclined; the *oblique rhomboidal prism*; Fig. 26. Boracic acid and sulphate of copper are examples.

Fig. 25.

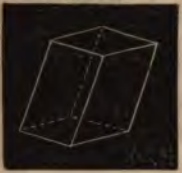
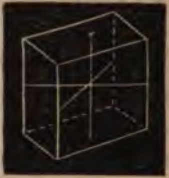


Fig. 26.



The *sixth* system, *Hexagonal* (Gr. *Hex*, six, *gōnia*, angle), has four axes, one vertical and passing through the intersection of the three equal horizontal axes, the angle between which is 60°. The *hexagonal prism*, Fig. 27, and the *rhombohedron*, Fig. 28, belong to this system. Familiar examples are seen in ice, iceland spar, quartz, and cinnabar.

Fig. 27.

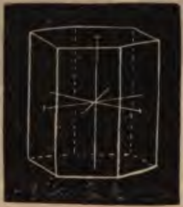
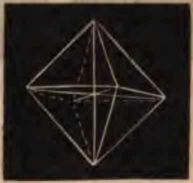


Fig. 28.



121. **Formation of Crystals.**—In order that crystals may form, the particles should be free to move over each other, hence the bodies should be fluid. Solid bodies

sometimes crystallise under the influence of long-continued vibration, or without apparent cause.

Wrought iron car-axles, couplings, etc., which are made up of bundles of fibres, and have great tenacity, sometimes become crystalline and break suddenly; tough, transparent, amorphous sugar (candy) will become after a time crystalline, opaque, and brittle.

122. **Methods of Procuring Crystals.** — From SOLUTION by *slow evaporation*. The larger the quantity of liquid, and the more gradual the evaporation, the larger and more perfect will be the crystals. *A hot saturated solution* allowed to cool deposits the excess of dissolved matter in crystals. Foreign bodies, as sticks, introduced, favour crystallisation, the crystals depositing on them as a nucleus; this is frequently seen in urinary calculi. *Chemical* and *electrical precipitation* often give crystals. A liquid obtained by fusing a solid will often crystallise. When a solid is sublimed (57), crystals are obtained.

123. **Useful Applications.** — When two bodies of different solubility are dissolved in the same liquid, as the liquid is evaporated, the *least* soluble crystallises first. Thus, in making salt from sea-water, the common salt first crystallises, forming a crust which is scraped off, leaving behind the *mother liquor*, which contains the more soluble sulphate of magnesia, chloride of potassium, etc.

Crystalline form is generally an *index* of *purity*, and it is exceedingly difficult to determine the true chemical constitution of an amorphous (Gr. *a*, not, *morphe*, form) body.

As bodies generally crystallise in the same form, we are often enabled thus to identify them. Some bodies crystallise in two systems; these are termed *dimorphous* (Gr. *dis*, twofold, *morphe*, form). The properties of dimorphous bodies often differ remarkably with the crystalline form.

Sulphur crystallised in the third system has a density of 2·04; in the fourth, of 1·98. Red iodide of mercury is scarlet in the fourth, and yellow in the second. It may be converted into the latter form by heating, and returns to the former by friction.

II. ADHESION

May take place between solids (striction, cements); solids and liquids (wetting, capillary attraction, solution, dialysis); solids and gases (absorption); between liquids (solution, diffusion, osmose); liquids and gases (absorption); between gases (diffusion).

124. Between Solids. — Pieces of flat glass may adhere so closely as to be inseparable, and show no sign of the junction on being cut with the diamond. This is termed *striction*, as distinguished from friction or passive resistance to motion, which can only take place during motion. *Cements* are fluid or semi-fluid bodies which adhere to solids and bind them together.

The line between cohesion and adhesion cannot be sharply drawn; iron and platinum may be welded at high temperatures, and dough, putty, or soft clay, under ordinary circumstances.

125. Between Solids and Liquids. Wetting. — The hand plunged into water is wetted; into mercury, not. In one case the liquid adheres to the surface; why it does not in the second cannot be explained. Mercury will wet brass or gold or lead, but not glass or iron.

If a clean scale pan be put on the surface of water in a dish, it will be found that a very considerable weight will be required in the other pan to draw it away; it is not even then separated from the water, a film of which adheres to the bottom of the pan; the weight is then the measure of the cohesion of the water, not of the adhesion of the pan. The statement so often made in text-books, that in liquids the cohesive and repulsive forces are in equilibrium, is inaccurate, as is shown by the foregoing experiment, as well as by the spheroidal form of drops of liquid when not wetting a surface, as in the dew-drop, or water sprinkled on a dusty floor or a hot plate.

126. **Capillary Attraction** — (Lat. *capillus*, a hair). When tubes of fine bore are plunged into a liquid capable of wetting them, the liquid rises within and without; within to a height much greater than without, and higher as the diameter of the tube is less. If the liquid do not wet the tube, a corresponding depression takes place. The form of the surface is concave in the first case, and convex in the second. The height varies with the nature of the liquid, and is *nearly* inversely as the diameter of the bore.

The cause of the rise of the liquid is readily understood; the attraction of the liquid for the sides of the tube causes it to draw itself up, and as the weight of the column is comparatively slight, it rises until that weight and the cohesive force of the liquid balance its attraction for the tube. This also accounts for the concave *meniscus*. The cause of the depression is not so easy to understand without the aid of mathematical demonstration. Any liquid under the influence of its cohesive force alone will assume the form of a sphere, as in oil suspended in a mixture of alcohol and water of the same specific gravity, (Plateau's experiment). Gravity flattens this sphere into a spheroid, as in a dew-drop. Adhesion spreads it out, as when water is sprinkled on a clean table. The liquid in a tube not being capable of being wetted by it, is under the influence of the two former forces only. It is hardly necessary to say that the phenomena are not due to repulsion.

Phenomena due to Capillarity. — Fluids rise in the wick of a lamp, and as they are burned or evaporated a new supply is furnished. A capillary tube, if filled, will not run over if broken off, but the liquid will remain at the top. Water does not freeze at 32° F. in capillary tubes, and if not allowed to reach the ends of the tube, liquids evaporate very slowly. A small greased needle will float on the surface of water. Floating bodies, when wetted, collect in groups or apparently adhere to the sides of the vessel. Ropes are contracted with immense force on being wetted, and rocks may be split by the expansion of wooden wedges driven into holes and wetted. In dry seasons the moisture of the subsoil is brought nearer the surface of the porous ground. Capillarity is diminished by heat.

127. **Solution.**—When the particles of a solid and liquid mutually interpenetrate, the former disappears, and is said to be dissolved. It still retains its general properties, as smell, taste, colour, and, on evaporating the liquid, is recovered unchanged. The dissolving liquid is called a *menstruum;* the most universal solvent is water, next glycerine, then alcohol. Why some bodies are soluble and others insoluble in a given menstruum, cannot be explained. Solution is favoured by circumstances diminishing cohesion, as powdering and heat; also by stirring, which favours intermixture. When a menstruum refuses to take up any more of a body, it is said to be *saturated.* A liquid saturated with one substance may still take up another, provided it be more soluble. Fine crystals that have become soiled may be safely washed with a saturated solution of the same ingredient. Although heat generally favours solution, yet lime and some of its salts are most soluble in cold water,and sulphate of soda at 92° F.

The term *solution* is also generally but inaccurately applied to certain chemical operations. Thus, a piece of silver thrown into nitric acid disappears with the evolution of orange-red fumes. It is said to be *dissolved* in the nitric acid. This is not strictly true, for, on evaporating, transparent crystals soluble in water are obtained, but no metallic silver. The change is more complex, the silver has been oxidised by the oxygen of the nitric acid, and a *base,* oxide of silver, formed; this again has combined with another portion of acid and nitrate of (the oxide of) silver formed. We have, however, at present no good substitute for the word thus loosely used.

128. **Dialysis** (Gr. *dia,* through, *lusis,* separation).—Bodies in solution may be divided into two classes: *crys-* [illegible] *se* which tend to crystallise; and *colloids* (Gr. [illegible] those which do not, but form on evaporation

a jelly-like mass. On putting a mixture of a crystalloid and a colloid into a vessel furnished with a bottom of parchment or similar material, the crystalloid will pass through while the colloid remains. Colloids exist in two forms, — one a clear solution, as white of egg in water (peptised, Gr. *pepsis*, coction), or opalescent, and as the same white of egg coagulated (pectised, Gr. *pektos*, coagulated). Many bodies pass readily from the first to the second condition.* Dialysis must be constantly taking place in the animal body.

Among the applications of this interesting discovery may be mentioned the preparation, in a soluble state, of bodies heretofore only known as insoluble. Among these are silica, sesquioxide of iron, stannic acid, Prussian blue. Urea and salts are separated from urine, and crystalline poisons from organic mixtures. It must be borne in mind, however, that the process of separation cannot be complete. The nutritious juice of flesh has been obtained from waste brine by dialysis, and it is proposed to render salt meat fresher by the same process.†

129. BETWEEN SOLIDS AND GASES. ABSORPTION. — On plunging a bright knife-blade into water, the adherence of bubbles of air will be noticed; this takes place to a less degree when the surface is roughened. The absorbing power of porous bodies is marked on account of the extensive surface they present. The retention of odours by the hair and clothing is a familiar example. Freshly burned charcoal will absorb 90 times its volume of ammonia, 85 of hydrochloric acid, 65 of sulphurous acid, 55 of sulphuretted hydrogen, 40 of nitrous oxide, 35 of carbonic acid, 35 of olefiant gas, 9·42 of carbonic oxide, 9·25 of oxygen, 7·4 of nitrogen, 5 of marsh gas, 1·75 of hydrogen. The five gases last named are permanently elastic. Gases easily liquefied are most largely absorbed, and

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* GRAHAM, *Phil. Trans.*, June, 1861. ODLING, *Chem. News*, March, 1862. BRANDE & TAYLOR, 134.

† WHITELAW, *Chem. News*, March, 1864.

in some cases the pressure from their condensation is enough to liquefy them. The deodourising powers of dry charcoal (206) depend upon this absorption and condensation. Platinum, when finely divided, (platinum sponge or black,) possesses similar properties.

130. Between Liquids. Solution. — As a general rule, liquids are indefinitely soluble in each other. In some cases a point of saturation may be reached. Ether is soluble in ten parts of water, and water in ten of ether.

131. Diffusion. — Two liquids brought into contact without stirring will gradually intermingle or diffuse. The phenomena are best studied by placing in a jar of one liquid a phial containing the second. The laws governing the rate of diffusion of liquids have been determined by Mr. Graham, but they are too complex to be discussed fully in an elementary work. In solutions, the quantity of dissolved substance diffused in the same time is proportioned to the strength of the solution. Common salt, hydrochloric and sulphuric acids have great diffusive power; albumen is very feeble in this respect. No direct relation exists between the specific gravity of a solution and its rate of diffusion.

132. Osmose (Gr. *ōsmos*, impulsion). — The diffusion of liquids through porous partitions. — If a piece of gut be partially filled with milk, tied at both ends, and immersed in water, it will after a time be found to be distended, while the water is slightly coloured by the milk. If a bladder, filled with molasses and fitted with a tube, be immersed in a jar of water, the molasses will rise in the tube, while the water will slowly become sweetened. In these cases, the water evidently passes through faster than the other liquid. The same effect is seen when saline solutions are used. It is to this action that the rise of sap in trees is due, and it probably plays an important part in animal physiology. Osmose is *increased* by heat.

The cause of osmose are: 1. The diffusive tendency of the liquids. 2. Capillary attraction. 3. The unequal absorption of the liquids by the septum, the one most readily absorbed passing the most rapidly. 4. Chemical action on the septum, the liquid acting the most passing the most rapidly. It cannot be due to capillary attraction alone, as is asserted by some physiologists, for capillarity is diminished, but osmose increased, by heat.

133. BETWEEN LIQUIDS AND GASES. ABSORPTION.—The amount of gas which a liquid will take up is directly as the pressure, and diminishes with the temperature. Such solutions have a lower boiling-point than the liquids themselves, and possess, generally, the properties of the dissolved gases. When in water, they are known in the Pharmacopœia as *Aquæ*, as *Aqua Chlorinii*, *Aqua Acidi Carbonici.* Water at 59° F., and under atmospheric pressure, dissolves 727·2 vols. of ammonia, 458 of hydrochloric acid, 43·6 of sulphurous acid, 3·23 of sulphuretted hydrogen, 2·36 chlorine, 1 of carbonic acid, 0·030 of oxygen, 0·0147 of nitrogen, 0·019 of hydrogen.* These are all expelled by prolonged boiling.

The greater solubility of oxygen, when compared with nitrogen, will account for its being found in larger proportion in the air contained in natural waters.

134. BETWEEN GASES. DIFFUSION.—If we put into a bottle liquids of different density, and insoluble in each other, as water, oil, and mercury, they will arrange themselves in the order of their specific gravities. This is not the case with gases. If we connect two globes, one filled with oxygen and the other with hydrogen, by means of a narrow tube, the one containing hydrogen being above that filled with oxygen, they will be found to intermingle, and form a permanent, homogeneous mixture, although the oxygen is 16 times as heavy as the hydrogen,—a greater difference of specific gravity than exists between mercury and water. The law regulating this phenomenon is that

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* BUNSEN, *Gasometry*, p. 286.

the rate of the diffusion is inversely as the square root of the density of the gas. Thus, hydrogen will diffuse into oxygen four times as fast as oxygen into hydrogen.* The constant constitution of our atmosphere depends upon this law.

The diffusion of hydrogen into air is strikingly shown by holding a jar of hydrogen over an inverted porous cell, into which has been fastened a glass tube, the lower end of which dips into water; the hydrogen rushing into the cell faster than the air escapes, causes a condensation which forces the air in bubbles from the lower end of the tube. The separation of gases by means of their unequal diffusibility through porous partitions is termed Atmolysis.† When gases pass through certain membranes, they deviate from the above law, those most easily liquefied passing most readily. This is owing to the condensing power of the membrane, and does not really invalidate Mr. Graham's law given above. The *effusion* of gases, or their passage through small openings in thin plates into a vacuum, obeys the same law.

CHEMICAL AFFINITY

135. Causes the particles of different bodies to unite, with the loss of *specific identity*. By specific identity we mean the properties by which a body is recognised. The term, derived from the Latin *affinis*, a liking, merely expresses the fact that certain bodies tend thus to unite, without attempting to explain this tendency. The strength of affinity varies exceedingly, some bodies, as chlorine or oxygen, uniting actively with nearly all the elements; others, as carbon, boron, and silicon, combining with but few, to form compounds of comparatively feeble stability.

136. **Admixture and Combination.**—*Adhesion* produces the admixture of bodies; *affinity* their combination. In the first the properties of the constituents may be recog-

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* GRAHAM, *Chemistry*, Am. ed., p. 87.

† GRAHAM, *Comptes Rendus*, t. LVII., p. 181.

nised; in the second they are lost. Bodies merely *mixed* may be separated by mechanical means; when *combined*, only by chemical means. Bodies may be *mixed* in any proportion; they *combine* in *definite* and *fixed* proportions.

Thus, if we mix sulphur and iron filings, we may distinguish the constituents by the eye, the iron may be withdrawn by the magnet, or the sulphur dissolved out by bisulphide of carbon. We may mix a grain of sulphur with a ton of iron, and *vice versa*, or in any intermediate proportion. If we apply heat to the mixture, the sulphur and iron combine to form a cinder-like mass not possessing any properties of either sulphur or iron. It cannot be decomposed except by some chemical agent, and if the sulphur and iron are not in the proportion of 4 to 7, the excess will remain out of combination.

In some cases of solution, as alcohol and water, there are phenomena partaking of the character of those of combination. In certain instances the properties of bodies are not entirely lost, as in carbonate of ammonia, and rare examples of decomposition by mechanical means may be mentioned (161).

137. **Circumstances Influencing Combination.**—Chemical combination is opposed by *cohesion;* it is favoured by *light, heat, electricity, catalysis,* the *nascent state,* and *mechanical force.*

138. **Cohesion** opposes chemical affinity by retaining in the respective masses the particles which tend to leave them and combine. It is overcome by powdering, fusion, or solution.

Iron in mass requires an intense heat for its combustion,—that is, its combination with the oxygen of the air. In the form of filings it burns brilliantly in a spirit-flame; in that of Quevennes iron (*Ferrum Redactum*, U. S. P.) it ignites like tinder, and in still finer powder will take fire spontaneously (pyrophyrus). Fusion and solution not only overcome cohesion, but facilitate the mixture of bodies. Seidlitz powders may be kept mixed in a dry place for any length of time, but on water being added combination at once takes place. Iodine and sulphur are fused together in making iodide of sulphur.

139. **Light** favours combination. Mixed chlorine and hydrogen may be kept for an indefinite period in the dark; in diffused daylight they combine slowly; in the sunlight,

explosively. The chemical or *actinic* power of light resides chiefly in and beyond the violet ray. The subject will be more fully discussed under DECOMPOSITION (156).

140. **Heat** is the most usual method of causing combination. Oxygen and hydrogen will not combine when mixed until a flame is applied. The effect of heat in promoting combustion is familiar in lighting a fire, candle, or gas jet.

141. **Electricity** acts *indirectly*, by the development of heat when resisted, as in the electrical cannon or powder cup, and *directly*, as when nitrogen and oxygen are caused to combine by passing through them a series of electrical sparks.

In the electrical cannon an insulated wire, passing through the vent, is furnished with a knob; its inner end does not touch the opposite side of the cannon. A spark passing to the knob traverses the wire, and has to leap the space between its end and the side of the gun. The resistance of the mixed gases previously introduced develops heat, and they are caused to combine. In the powder cup, two stout wires are united by a fine one, around which gunpowder is placed. A single voltaic cell will cause explosion from the heat developed, owing to the resistance of the fine wire to the passage of the current. Both expedients are used in submarine blasting.

142. **Catalysis**—(Gr. *kata*, downwards, and *luō*, I loose). This term merely serves to group together a series of hitherto unexplained phenomena. Bodies appear to act by their *presence* alone. The alloy of silver and platinum will dissolve chemically in nitric acid; platinum alone is unaffected. The silver is said to act by catalysis or presence.

143. **The Nascent State**—(Lat. *nascens*, being born). Bodies which refuse to combine when in their ordinary or *free* condition, will do so when in the act of being liberated from combination. In this way large numbers of compounds are formed which could not be obtained by

any other means. The compounds of sulphur and phosphorus with hydrogen are examples.

Sulphur and hydrogen cannot be combined when free, but by uniting sulphur with iron, forming sulphide of iron, FeS, and throwing this into acidulated water, HO, a mutual interchange of atoms takes place, forming FeO, oxide of iron, and HS, sulphuretted hydrogen; the former combines with the acid.

144. **Mechanical Force.**—Long continued agitation will in rare cases determine combination. Olefiant gas, C_4H_4, (existing in ordinary coal gas,) hydrated sulphuric acid, and mercury, shaken for four days in a glass vessel, resulted in the production of alcohol.

This interesting discovery by Berthelot[*] has been applied on the large scale in France,[†] but without success in a commercial point of view. The reaction may be thus expressed: $C_4H_4 + 2HO = C_4H_6O_2$ (alcohol). The reaction is indirect, and will be more fully explained under *Organic Chemistry.*

LAWS OF CHEMICAL COMBINATION.

145. **Analysis and Synthesis.**—The laws which govern the formation of chemical compounds have been ascertained purely by experiment. The composition of a body may be determined by taking it apart (analysis, Gr. *ana, luō,* to separate), or in some cases by putting together its constituents in their proper proportions (synthesis, Gr. *syn, tithemi,* to put together).

146. **Laws.**—I. All chemical compounds are definite in their constitution, the ratio of their constituents being constant. Hence all bodies combine in certain definite ratios (equivalents, combining weights, atomic weights). See table (181).

II. Bodies combine either in their lowest ratio or a multiple of the same by a whole number.

III. The combining weight of a compound is the sum of those of its constituents.

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[*] *Chémie organique, etc.,* t. I., p. 104.

[†] *Chem. News,* Jan., 1863.

147. **Illustrations of these Laws.**—I. Pure water is found by analysis, no matter what its source, to consist of oxygen and hydrogen in the ratio of 8 of the former to 1 of the latter. If we mix the gases in this ratio and combine them, pure water results; if either be taken in excess, that excess will remain uncombined. Iron and oxygen combine in the ratio of 8 of oxygen to 28 of iron, and so by analysis of all known bodies the ratios in which their elements unite are ascertained and in many cases verified by synthesis. In order to render these ratios absolute, one body is fixed upon as a standard; hydrogen is generally taken as unity, having the smallest combining weight, and thus avoiding the inconvenience of large and fractional numbers. The proportions in which bodies unite are termed their *combining weights*, because they express the quantities which will exactly combine; *atomic weights*, because they are supposed to represent relative weights of their atoms or molecules; and *equivalents*, because one body taken in its ratio is equal in chemical effect to any other body taken in its ratio.

The use of a standard is merely a matter of convenience. It is obvious that we may take 1 of hydrogen to 8 of oxygen, or 10 of hydrogen to 80 of oxygen, and so on. When in practice we have a given quantity of a body, we ascertain the quantity of any other, necessary to combine with it by rule of three. Thus the combining weight of sulphur being 16, that of iron 28, to find how much sulphur is required to exactly combine with 100 lbs. of iron, we have 28 : 16 : : 100 : 57·14 lbs. of sulphur required. The meaning of the term equivalent will be better understood by an example. If in 9 grains of water, HO, we remove 1 grain of hydrogen and supply its place by iron, forming FeO oxide of iron, we must use 28 grains of iron which thus exactly unites with the oxygen and performs the same chemical part as 1 grain of hydrogen.

148. II. Water being composed of 1 part of hydrogen and 8 of oxygen, the next combination is hydrogen 1 part, and oxygen 16 or twice 8. We may have 14 of nitrogen (its combining weight) united with 8, 16, 24, 32, or 40 of

oxygen, but in no case does less than 8 of oxygen combine. This is true of all elements and compounds. It should be clearly borne in mind that the compounds formed by the second, third, fourth, etc., multiple of an element, differ as much from each other as the first compound did from its constituents, and the same is true of most compound bodies when united. The apparent exceptions to the second law in the case of *sesquioxides* will be noticed hereafter.

Calomel and corrosive sublimate differ only in the quantity of chlorine being double in the latter. The difference of the properties of various combinations of the same elements in compounds will be obvious when we come to the description of the bodies themselves.

149. III. Besides the elements, we have frequently to combine compound bodies. The most important of these are known as acids and bases. Any body which has a sour taste, will redden vegetable blues, and will combine with a second compound body to form a new third substance, is termed an *acid;* a *base* is any body capable of combining with an acid and neutralising it. An acid and a base united form a *salt.*

The above definitions are necessarily imperfect, as nature never defines. They will, however, do provisionally. We have a large class of salts (the haloid group, 224), of which common salt is an example, which are not formed by the union of an acid and a base.

To determine the combining weight of an acid or a base, it is only necessary to add up its constituents. Thus, hydrated sulphuric acid, $HO,SO_3=1+8+16+24=49$; potassa, $KO=39+8,=47$. These numbers are as invariable as those given in the table of elements (181), and might form a separate table, though the arithmetical process is so simple that this is not often done. When a known quantity of an acid or base is given, the amount necessary to saturate is determined as before by proportion.

Thus to neutralise 100 lbs. of hydrated sulphuric acid, HO,SO_3, with lime, $CaO=28$, we have 49 : 28 : : 100 : 57·1 lbs. lime. In practice, test papers are used to determine when saturation has taken place. The most common is litmus-paper, which is reddened by acids and has its colour restored by certain bases which neutralise the acid. By having a blue and a feebly reddened paper, and mixing gradually the acid and base, we can determine the proper quantity without the necessity of weighing.

150. **The Atomic Theory** of Dalton supposes that the relative weights of the atoms of bodies are those indicated by their combining weights. Of the absolute weight of the atoms we cannot even conjecture. Hydrogen being the lightest atom, that of oxygen would be eight times as heavy, iron 28 times, and so on. The atoms being supposed to have the same density, their relative bulk would correspond with their respective weights. Upon this theory, the laws of combination are easily explained.

Suppose a trillion of atoms to constitute an appreciable quantity; call this quantity n. As each atom of oxygen is eight times as heavy as one of hydrogen, the quantity n of oxygen will be eight times as heavy as the quantity n of hydrogen. When they combine, each atom of oxygen unites with one of hydrogen, and there being the same number of each, one trillion or n molecules of water, HO, will be formed. If, however, we take more atoms of hydrogen, $n+a$, where a represents the excess, than there are of oxygen, those in excess will be left uncombined, and we shall have the same n molecules of water and a of hydrogen will remain. This illustrates the first law.

An atom is indivisible. Hence, if we add more than one atom, we must take two, three, or more, and the weight of the added body will be in the ratio of its atomic weight multiplied by the number of atoms taken. Calling the weight of oxygen eight, if we add to an atom of nitrogen two of oxygen, they will weigh twice eight, and so on; what is true of a single atom is true of n atoms, or our supposed appreciable quantity. (Second law.)

A molecule is composed of two or more atoms; its weight, therefore, is the weight of its constituent atoms, and what is true of one molecule is true of n molecules, or our supposed appreciable quantity. (Third law.)

151. **Combination by Volume.**—It is easier to measure gases than to weigh them. By filling a vessel of known

capacity with water or mercury, and displacing this by an equal bulk of gas, its volume is at once determined. Knowing its specific gravity, the weight of this volume is found by multiplying the weight of an equal bulk of air by this specific gravity (193.)

151. GAY-LUSSAC'S LAW.—It is found that a very simple law governs combination by volume. Equal volumes (with certain exceptions) contain equal numbers of atoms, and hence are equivalent. If we take a given bulk of hydrogen, and call its weight unity, the weight of equal bulks of the following gases and vapours will be: nitrogen 14, chlorine 35·5, iodine (vapour) 127, water vapour 9, etc.; these numbers, it will be seen, are those of the combining weights of those bodies.

The most important exceptions to this law are oxygen, which with a combining weight of 8 has a density of 16, compared with hydrogen as 1; its volume is therefore but one-half that of hydrogen. The same is true of sulphur (at 1600° F., at which temperature its volume becomes constant), phosphorus, and arsenic; while ammonia, hydrochloric acid, alcohol, and some other compound vapours have a volume double that of hydrogen for an equivalent weight. The volume of oxygen being assumed as unity, that of hydrogen and its group is 2, that of the compound vapours above noticed 4. It will be seen that these bear a simple arithmetical relation to each other. In all cases where the term equivalent is used in this volume, it will refer to *combining weight*, unless otherwise specified.

152. SYMBOLS; NOTATION.—The object of chemical symbols is to express to the eye the elements existing in any body, with their exact proportions; also their supposed arrangement and the theoretical changes taking place during reactions. They are algebraic in their character, but not strictly so.

The initial letter of the Latin or English name represents *one equivalent*, or atom of the element. Thus O represents not only oxygen, but 8 parts by weight on the hydrogen scale. Where several elements begin with the same letter, a second *small* letter is added. Thus P stands for Phosphorus, Pt for Platinum, Pb for Plumbum (Lead), etc. When it is desired to express more than one equivalent *of an element,* the number expressing the quantity (*coefficient*) is placed at the right hand and below the line. Thus O_3, three atoms of oxygen; Pb_2, two atoms of lead.

Two elements combined together form a *binary* compound (Lat. *bis,* twice). This combination is indicated by simply joining the two symbols. Thus HO, water, is a combination of an atom of hydrogen with one of oxygen. The coefficient is placed to the left and on the line. Thus 2HO means two molecules of water, and is equal to H_2O_2.

In algebra, *ab* would signify $a \times b$; but in chemical notation no confusion can result, as a symbol represents a *substance* as well as a quantity. To speak of multiplying hydrogen by oxygen is manifestly absurd. A very common error with beginners is to multiply the *combining weight* instead of the *coefficient* of the elements by the coefficient of the compound. Thus, instead of $2HO = H_2O_2$, or $2Fe_2O_3 = Fe_4O_6$, we have H_2O_{16}, or $Fe_{112}O_{48}$; this blunder is most transparent, and yet it is exceedingly common with students.

A *ternary* compound is one containing three elements (Lat. *ter,* three times). In inorganic chemistry they are always made up of two pairs of elements, one element being common to both sides. Thus the two binaries KO, potassa, and SO_3, sulphuric acid, unite to form KO,SO_3, a ternary compound (sulphate of potassa). Binaries thus united have simply a *comma* placed between them. A coefficient placed as for binaries only affects as far as the comma, unless a parenthesis or vinculum is used. Thus, $6(KO,SO_3)$, or $6\overline{KO,SO}_3$, will represent six equivalents of sulphate of potassa.

The importance of the parenthesis may be seen by reducing the following formulæ to their elements. $3(AgO,PO_5) = Ag_3O_3, P_3O_{15}$; $3AgO,PO_5 = Ag_3O_3,PO_5$.

A *quarternary* compound (Lat. *quarto*, four times) in inorganic chemistry consists of two ternaries. The sign + is placed between them. They require the same use of the parenthesis as binaries. Thus, KO,SO_3+MgO,SO_3, double sulphate of potassa and magnesia. As a general rule, when a compound breaks up, it is first at the +mark, secondly at the comma, and lastly the elements separate.

Symbols are also used to explain the *theoretical changes* taking place during reaction. If we throw potassium, K, on water, HO, it unites with the oxygen, O, of the water, and sets free the hydrogen, H. This may be expressed thus, $HO+K=KO+H$. In this case the sign + merely has the algebraical significance of *addition*, and does not mean *combination*.

In writing symbols, the *electro-positive* element of a compound (164) is written first. For the present it will suffice to say that in binary compounds the metallic element is written first, and in ternaries the base.

153. NOMENCLATURE.—The object of chemical nomenclature is to indicate the composition of a body by its name. It is yet quite imperfect.

Before the time of Lavoisier the names given to compounds were empirical; many of these are retained as synonyms, and it is important for the student to learn both the systematic and the empirical names; a list will be found in the Appendix. The following are some examples: *Saccharum Saturni*, sugar of lead, acetate of lead; *Crocus Martis*, saffron of Mars, Colcothar, anhydrous sesquioxide of iron; *lapis infernalis*, lunar caustic, nitrate of (oxide of) silver.

All binary compounds terminate in *ide*, which is affixed to the abbreviated name of the *electro-negative* (164) constituent. Thus, FeO *ox*ide of iron, HgS *sulph*ide of mercury, NaCl *chlor*ide of sodium. The termination *uret* is synonymous, as sulphuret for sulphide, but is now disused in scientific works.

It is to be regretted that it has been retained for the sulphides in the last edition of the U. S. Pharmacopœia, while the other *urets* have been properly changed to *ides*.

The termination *ide* gives no indication of the proportions in which the elements are combined; this is done by prefixes. *Sub* (Lat. *under*), an excess of electro-positive element; *proto* (Gr. *prōtos*, first), one atom of each element; *sesqui* (Lat., half as much), two of positive to three of negative; *Deut* (Gr. *deuteros*, second), or *Bin* (Lat. *Bis*, twice), two of negative to one of positive; *ter* (Lat. *ter*, three times), three of negative. The following table will be useful in aiding the memory of the student, the signs + and — indicating the proportion of the elements first and last written.

+	—	PREFIX.	EXAMPLE.	
2 or more	1	Sub	Cu_2O,	Suboxide of copper.
1	1	Proto	FeS,	Protosulphide of iron.
2	3	Sesqui	Fe_2Cl_3,	Sesqui-chloride of iron.
1	2	Deut, or Bin	MnO_2,	Deut or Binoxide of Manganese
1	3	Ter	Sb_3,	Tersulphide of antimony.

These prefixes are also used with the same meaning for ternary compounds. Thus, $2PbO,C_4H_3O_3$, *sub*-acetate of lead; FeO,CO_2, *proto*-carbonate of iron; $2NH_4O,3CO_2$, *sesqui*-carbonate of ammonia; $KO,2CrO_3$, *bi*-chromate of potassa; $Fe_2O_3 3SO_3$, *ter*-sulphate of (the sesquioxide of) iron (inaccurate).

Confusion has arisen from putting the prefix of the base before that of the salt in which it occurs. Thus protosulphate and protocarbonate of iron are used to express either the proportions of acid and base, or the constitution of that base, generally the latter. The prefix *per* is used to signify any higher compound, and is often used for *sesqui*, as perchloride of iron for sesquichloride. It is indefinite, and should never be employed in this way.

154. OXYGEN ACIDS AND BASES.—When the name of a metal ends in *ium*, and it becomes oxidised, so as to form a *base*, the last syllable changes to *a*. Thus: potassium, *potassa;* sodium, *soda;* magnesium, *magnesia*. This rule is of limited application; where not applied, the name

of the metal in the base is used, the oxygen being understood. Thus, nitrate of silver for nitrate of the oxide of silver.

The most usual termination of an ACID is in *ic*, the rarer termination *ous* being used to signify a lower degree of oxidation; thus, SO_3 sulphur*ic* acid, SO_2 sulphur*ous*. The prefix *hyper* (Gr. *huper*, above) is used to indicate a higher degree of oxidation, and *hypo* (Gr. *hupo*, under) a lower one; the former is generally abbreviated to *per*, as chlor*ic* acid, ClO_5; *hyper* or *per*-chlor*ic*, ClO_7; *hypo*-chlor*ic*, ClO_4. When an acid combines with a base to form a salt, the termination *ic* changes to *ate*, *ous* to *ite*, the prefixes being unaltered. These rules are illustrated in the following series.

Compounds of Chlorine with Oxygen, and their Salts.

ClO_7	Hyper (per)	chlor*ic*	acid	KO,ClO_7	*Per*	chlor*ate*	of	potassa.
ClO_5		chlor*ic*	"	KO,ClO_5		chlor*ate*	"	"
ClO_4	Hypo	"	"	KO,ClO_4	*Hypo*	"	"	"
ClO_3		chlor*ous*	"	KO,ClO_3		chlor*ite*	"	"
ClO	Hypo	"	"	KO,ClO	*Hypo*	"	"	"

Care must be taken not to confound *ite* with *ide*. The former contains the letter *t*, which stands for *ternary*; the latter *d*, for *dual* or binary; this will aid the memory.

There is no systematic nomenclature for acid, bases and salts not containing oxygen.

The name of an acid only indicates its elements, and not their proportions. These must be retained by memory. The number of important oxygen acids in inorganic chemistry is not great, and they are arranged in the table below in a manner calculated to enable the student easily to commit them to memory. The symbols represent the acids when *dry* or in *combination;* in the free state they are practically (except CO_2 and CrO_3) combined with water.

Combined Oxygen Acids.

PO	Hypo-phosphorous.	CO_2	Carbonic.
ClO	Hypo-chlorous.	SO_2	Sulphurous.
S_2O_2	Hypo-sulphurous.	SnO_2	Stannic.

NO_3	Nitrous.	NO_5	Nitric.
SO_3	Sulphuric.	PO_5	Phosphoric.
PO_3	Phosphorous.	ClO_5	Chloric.
SiO_3	Silicic.	BrO_5	Bromic.
BO_3	Boracic.	IO_5	Iodic.
MnO_3	Manganic.	SbO_5	Antimonic.
FeO_3	Ferric.	AsO_5	Arsenic.
CrO_3	Chromic.	BiO_5	Bismuthic.
AsO_3	Arsenious.		
AuO_3	Auric.	Cr_2O_7	Perchromic.
		Mn_2O_7	Permanganic.
NO_4	Hyponitric.		
ClO_4	Hypochloric.		

DECOMPOSITION

155. Is the breaking up of a compound body into simpler forms. It may be considered under two heads. (1) Where the constituents of a body separate and remain so, or form new compounds among themselves,—*decomposition proper* (spontaneous [?] decomposition). (2) Where decomposition is effected by the agency of some other body, with which an interchange of constituents takes place,—*decomposition by superior affinity*.

I. DECOMPOSITION PROPER.

This is seen in all organic bodies after death, under favourable conditions as to temperature and moisture. It is improperly termed spontaneous, as no change can take place in matter without the agency of force. It is favoured by light, heat, electricity, catalysis, example and mechanical force.

156. **Light.**—The chemical or actinic power of light resides chiefly in the violet ray, and beyond this where light is invisible, unless concentrated by a lens, when it is lavender-coloured. The effect of light in causing decomposition is seen in the fading of colours, the

growth of vegetation, and it is applied in the art of photography.

Carbonic acid, CO_2, is exhaled by animals, and is a product of ordinary combustion. It is absorbed by vegetables and, under the influence of sunlight, decomposed, the oxygen being exhaled and the carbon assimilated. This beautiful balance of animal and vegetable existence is applied in the well-known aquarium.

The principle of the art of photography is easiest understood by a description of the daguerreotype. In all cases the steps are four: 1. To render the plate sensitive to light; 2. To expose it; 3. To develop the image; 4. To fix it.

1. A polished silver surface is exposed to the vapour of iodine in a chemically dark room. Iodide of silver, AgI, is formed. This undergoes a change (more probably molecular than strictly chemical) on exposure to light. An image of the object is received at the focus of a convex lens, in a dark box (camera), on a plate of ground glass. 2. This is removed, and the sensitive plate inserted. Objects are visible by the light which they irregularly reflect, white bodies reflecting the most and black the least. The iodide of silver is most changed when there is most light, and thus gives a picture. 3. In order to render this visible, the plate is exposed to the vapour of mercury, which adheres most where there has been most change. 4. To prevent further change, the unaltered iodide of silver is removed by a solution of cyanide of potassium. All photographic processes are more or less alike in general principle.

157. **Heat.**—Limestone, CaO,CO_2, when heated, is decomposed, the fixed lime, CaO, remaining, and the volatile, CO_2 passing off. Gunpowder consists of charcoal, nitre, and sulphur. When fire is applied, it is converted into heated gases, occupying an enormously increased bulk. In symbols the change taking place, when the powder is not confined, may be expressed thus: $C_3+KO,NO_5+S=3CO_2+N+KS$, the latter forming the smoke.

158. **Electricity** may act indirectly by developing heat when resisted (141), and directly in the case of voltaic decomposition. The latter will be considered under a distinct head, ELECTRO-CHEMISTRY (162).

159. **Catalysis** (142).—Chlorate of potassa, when heated

to redness, fuses and gives off all its oxygen rapidly, $KO, ClO_5 = KCl + O_6$. If mixed with powdered sand or black oxide of manganese, the gas comes off quietly, and at a much lower temperature. The black oxide is unchanged, and may be used over and over again.

160. **Example.** — A solution of pure sugar will not ferment; upon the addition of a small quantity of any fermenting matter, as yeast, decomposition begins, and continues until the sugar is broken up. The ferment is said to act by *example*. We do not really know how it acts.

161. **Mechanical Force.** — Although, as before stated (135), it is generally true that a chemical compound may be decomposed only by chemical means, yet there are important exceptions. In some cases the action is indirect, as when heat is developed by friction or percussion; in other cases it is direct. The two salts, sulphate of alumina and sulphate of potassa, which united constitute alum, may be separated by their different rates of diffusion (131). Neutral metallic salts, such as those of gold, silver, platinum, and copper, are decomposed by filtering through charcoal, the metal being deposited on the charcoal. This is due to the enormous surface which the porous charcoal exposes (206).

ELECTRO-CHEMISTRY.

162. When a voltaic current is passed through an electrolyte (94), decomposition takes place. If the liquid to be studied be put into a separate vessel (decomposing
nd the conducting wires be tipped with platinum or
constituents may be separated and examined.

ential Phenomena. — The amount of chemical
battery cells, of electricity developed, and of
decomposition in the decomposing cell, are *equiv-*

alent. With the same electrolyte the same constituent appears invariably at the same pole.

Thus for 32·5 grains of zinc, Zn, dissolved in the battery, 9 grains of water, HO, are decomposed, 40·5 grains of oxide of zinc, ZnO, formed, and 1 grain of hydrogen, H, liberated. The electricity thus generated will, if passed through water, decompose 9 grains $(H=1.O=8)$, but if through iodide of potassium, KI, $(K=39.I=127)$, 166 grains, or one equivalent will be broken up. The oxygen in the first case, and the iodine in the second, appear at the end of the wire attached to the + or platinum pole. By measuring the amount of gas liberated in a given time, the relative quantity of the current may be determined. An instrument for this purpose is called a voltameter.

164. ELECTRO-POSITIVE AND NEGATIVE BODIES. — We have thus a means of arranging simple and compound bodies according to their relative electrical characters. These may be determined: 1. By the decomposing cell, the — body going to the + pole (95). 2. By a simple cell, the direction of the current being indicated by a galvanometer. 3. Of two metals immersed in an electrolyte and joined, the + alone is corroded. Of all the elements, oxygen is the most negative, cœsium the most positive. The metals generally are positive to the non-metallic bodies. Acids, and all corrosive agents, are negative, bases positive.

No absolutely accurate scale of the relative electrical position of the elements can be made. The direction of the current in a single cell varies with the electrolyte, and the compounds of some of the elements, as nitrogen, have not as yet been decomposed.

The following list is approximate only; each element is positive to all below it, and negative to all above; the less important elements have been omitted.

Electro-Chemical Order of the Principal Elements.

Electro-negative.
Oxygen.
Fluorine.
Chlorine.
Bromine.
Iodine.
Nitrogen.
Sulphur.

Phosphorus.
Arsenic.
Chromium.
Tungsten.
Boron.
Carbon.
Antimony.
Silicon.
Hydrogen.
Gold.
Platinum.
Mercury.
Silver.
Copper.
Bismuth.
Tin.
Lead.
Cadmium.
Cobalt.
Nickel.
Iron.
Zinc.
Manganese.
Aluminum.
Magnesium.
Calcium.
Strontium.
Barium.
Lithium.
Sodium.
Potassium.
Electro-positive.

The two newly-discovered metals, cœsium and rubidium, are more electro-positive than potassium.

THESE TERMS RELATIVE.—As we know of no absolutely positive or negative state, we speak only of a body in reference to some other combined with it. Thus, zinc is negative to potassium but positive to tin, which again is positive to gold. Chlorine is positive to oxygen in hypochlorous acid, $\overset{+}{\mathrm{Cl}}\overset{-}{\mathrm{O}}$, but negative to hydrogen in hydrochloric acid, $\overset{+}{\mathrm{H}}\overset{-}{\mathrm{Cl}}$.

165. **Voltaic Protection of Metals.**—If a plate of zinc and one of copper be exposed to a moist atmosphere, they will both, after a time, rust; if joined together, the copper remains bright. In the second case a simple voltaic circuit is formed, the electrolyte is polarised, the non-corrosive hydrogen atoms face the — copper, and *vice versa.* This principle is applied in Dr. Hare's lightning-rod (93).

Other illustrations may be mentioned. A tinned basin rapidly corrodes when the coating is scratched through, because iron is positive to tin; if coated with zinc, which is positive to iron, the latter metal is preserved (galvanised iron). Iron-clad vessels speedily foul and corrode in salt water, because of impurities in the iron causing local action (97), and still more rapidly when they are coppered below the water-line only, or when copper pipes pass through them.

166. **Electrotype.**—This is the name given to the art of cold casting of metals by electricity. As the metals are electro-positive, they will deposit from solution upon a conductor attached to the negative (zinc) pole. By proper management they may be obtained of any desired thickness, amorphous and bright, or dead. A gentle current, not enough to evolve hydrogen at the — pole, is required. The process is largely employed in the arts, not only for plating and gilding, but for copying maps, engravings, and medals, facing type, etc.

In silver plating, a solution of cyanide or oxide of silver is made in cyanide of potassium. To the + pole is attached a plate of silver, to the negative the object to be plated. A feeble current is passed, the cyanide of silver is decomposed, the — cyanogen* combining with the silver pole, and a corresponding quantity of silver being deposited upon the object at the negative pole. Suppose the object to be plated to be of copper, the change may be represented as follows:

$$-\mathrm{Cu}\mid\overbrace{\overset{+}{\mathrm{Ag}}\,\overset{-}{\mathrm{Cy}}}\quad\overbrace{\overset{+}{\mathrm{Ag}}\,\overset{-}{\mathrm{Cy}}}\quad\overbrace{\overset{+}{\mathrm{Ag}}\,\overset{-}{\mathrm{Cy}}}\mid\mathrm{Ag}+\text{ before decomposition.}$$

$$\overbrace{\overset{-}{\mathrm{Cu}}\,\overset{+}{\mathrm{Ag}}}\mid\overbrace{\overset{-}{\mathrm{Cy}}\,\overset{+}{\mathrm{Ag}}}\quad\overbrace{\overset{-}{\mathrm{Cy}}\,\overset{+}{\mathrm{Ag}}}\quad\overbrace{\overset{-}{\mathrm{Cy}}\,\overset{+}{\mathrm{Ag}}}\mid\text{ after decomposition.}$$

II. DECOMPOSITION BY SUPERIOR AFFINITY

167. This may be divided into single and double decomposition.

Single decomposition takes place between three bodies, two of which are united, the third by combining with one of these liberates the other. The general expression of the change is:

$$\overset{+}{A}\overset{-}{B}+\overset{\pm}{C}=\overset{+}{A}\overset{-}{C}+\overset{+}{B}\text{ or }\overset{+}{C}\overset{-}{B}+\overset{+}{A}.$$

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* Cyanogen is a compound body acting as an element and resembling chlorine in its chemical relations (224).

Thus when potassium is thrown upon water (152),

$$\overset{+}{H}\overset{-}{O}+\overset{+}{K}=\overset{+}{K}\overset{-}{O}+\overset{+}{H};$$

or when sulphuric acid is added to carbonate of soda,

$$\overset{+}{NaO},\overset{-}{CO_2}+\overset{-}{SO_3}=\overset{+}{NaO},\overset{-}{SO_3}+\overset{-}{CO_2}.$$

The water of the sulphuric acid is omitted for the sake of simplicity; it does not enter into the reaction.

168. **Double Decomposition** takes place between two pairs of elements or binaries (152). These mutually interchange constituents. The general formula is:

$$\overset{+}{A}\overset{-}{B}+\overset{+}{C}\overset{-}{D}=\overset{+}{A}\overset{-}{D}+\overset{+}{C}\overset{-}{B}.$$

Thus, when solutions of sulphate of potassa and nitrate of baryta are mixed, a white cloud (precipitate) falls. This is sulphate of baryta, nitrate of potassa remaining in solution,

$$\overset{+}{BaO},\overset{-}{NO_5}+\overset{+}{KO},\overset{-}{SO_3}=\underset{\downarrow}{\overset{+}{BaO},\overset{-}{SO_3}}+\overset{+}{KO},\overset{-}{NO_5}\rightarrow *$$

It is obvious that both acids and bases at the time of the interchange are in a nascent state (143), hence we get many compounds by double decomposition exclusively.

169. The circumstances most prominently affecting these forms of decomposition are *insolubility*, *volatility*, and *mass*.

170. **Insolubility.**—Where the compound of any two of the constituents of two given soluble compounds is insoluble, that compound will be formed on mixing them. Hence it is not possible to give lists of the relative *strength* (so called) of the various acids and bases, for an acid or a base may be driven out of combination by one much more feeble in the ordinary sense of the term, provided the circumstances modifying decomposition come into play.

Thus potassa will displace baryta in soluble combination. If we add solution of potassa to nitrate of baryta, we will have

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* An arrow pointing downwards indicates that the body is precipitated; when horizontal, that it remains in solution; when pointing upwards, that it is liberated as gas. The signs + and — refer to the electro-positive and electro-negative constituents.

$BaO,NO_5+KO,HO=BaO,HO\overset{\rightarrow}{+}KO,\overset{\rightarrow}{NO_5}$. But if *sulphuric* acid be combined with potassa, the baryta will form an *insoluble* compound with it and displace the potassa, $KO,SO_3+BaO,HO=BaO,\underset{\downarrow}{SO_3}+KO,HO\rightarrow$. This fact is applied in testing in the humid way (174).

171. **Volatility.**—At the same temperature where affinities are nearly balanced, the more fixed body will displace that which is the more volatile. Hence, compounds of gaseous acids and bases, as carbonic acid and ammonia, are easily decomposed. And at high temperature, comparatively feeble fixed acids, as boracic, silicic, and phosphoric, will displace the strongest.

Carbonic acid, which is a gas at ordinary temperature, is driven out of combination by all other acids, except the hydrocyanic; under favorable circumstances, as when in solution under pressure, it shows the properties of a powerful acid, dissolving rocks which are unaffected by all other acids except the hydrofluoric. Boracic acid has no sour taste, and barely reddens litmus; it is, perhaps, at ordinary temperature, the feeblest of acids, but at a red heat, above which it volatilises, it will drive sulphuric acid, which boils at 640°, from its combinations.

172. **Mass.**—The quantity of material will sometimes determine the direction of chemical change. If we pass steam over red-hot iron filings, the oxygen of the vapour of water will unite with the iron, and hydrogen will pass over. If this be collected and the steam generator detached, upon passing the hydrogen back over the red-hot oxide of iron, it will take up its oxygen, reform steam, and leave metallic iron.

ANALYSIS

May be divided, according to its object, into *Qualitative* and *Quantitative*, and, according to the method pursued, into *wet* or *humid*, *dry*, *by the balance* and *volumetric*.

173. **Qualitative Analysis** seeks only to determine the nature of a body. Often a body may be recognised

by its physical properties, such as colour, lustre, taste, smell, solubility, hardness, crystalline form, and specific gravity.

Thus the mineralogist can distinguish most of his specimens, and even their localities. In the *dry* way we are assisted by the blowpipe (212). The behaviour of a body in the outer (oxydising) or inner (reducing) flame, the colour given to fluxes, enables us to decide on its character in a rapid and satisfactory manner.

174. **Liquid Tests. Reagents.** — To determine the presence of a body in solution, we have only to add another which contains a substance capable of forming an insoluble compound with one of the constituents of the former. A *precipitate* falls (168), and by its colour, solubility or insolubility in excess of the reagent, or in other reagents, the nature of the body may be determined. This method is applicable where we are seeking to determine simply the presence or absence of a body without regard to the nature of those with which it may be associated. When all the constituents of a body are to be determined, we have to proceed in a more complex manner. A *diagnosis by exclusion* is a preliminary step, adding a reagent, as sulphuretted hydrogen, which precipitates a very large number of substances. The absence of a precipitate at once excludes these and narrows the inquiry to that extent. In case of a precipitate, the colour, etc. are noted, and by successively applying other reagents a final conclusion is arrived at.

Examples. — If to a solution suspected to contain copper we add ferrocyanide of potassium (340), the absence of a precipitate or the presence of a brown one would be decisive. If to water supposed to be impure we add sulphydrate of ammonia (380), the appearance of a black precipitate indicates the presence of either lead, tin, bismuth, mercury, cobalt, nickel, silver, gold, platinum, iron, copper, or uranium. To determine which of these is present, other reagents must be used. The tests will be given with the various elements and compounds.

175. **Delicacy of Tests.** — The delicacy of a liquid test

depends (1) upon the insolubility of the precipitate; (2) upon its opacity. If we add sulphuric acid to a soluble salt of lime in strong solution, we get a precipitate of sulphate of lime; but if the quantity of water be greater than 400 times the weight of the sulphate of lime formed, it will dissolve as fast as formed. Magnesia and alumina are very insoluble, but form gelatinous opalescent precipitates which may escape the eye, while those formed by sulphuretted hydrogen or ferrocyanide of potassium with the heavy metals are very opaque, and will be visible even when in very small quantity. In comparing the delicacy of tests, we always suppose the same quantity of solvent to be used. In certain cases, (sulphocyanide of potassium with salts of the sesquioxide of iron, for instance,) *no precipitate* is formed, but a distinct colour which forms sometimes a very delicate test.

176. **Spectral Analysis.**—By passing the light of a flame through a prism or series of prisms, a spectrum is obtained (30). That of the sun is intersected with numerous lines (Fraunhofer's lines). If into the flame we introduce a loop of wire containing a small portion of a combustible or volatile body, a line or lines make their appearance. These lines are constant in their position and colour for the same body. Where the light from one substance placed in the flame is caused to pass through its own flame, the two neutralise, and a black line is seen. All bodies do not yield satisfactory spectra.

The delicacy of this test is very great. Bunsen and Kirchoff, to whom we principally owe its discovery, calculated that they had detected the $\frac{1}{800000000}$ of a grain of sodium. The new metals Cœsium, Rubidium, Thallium, and Indium were discovered by its means, and observers are now making investigations into the probable constitution of the sun and stars by its aid. It is stated that the position and colour of the lines vary, in some cases, with the temperature.

177. **Quantitative Analysis** seeks to determine not

only the nature of a body, but the exact amount or quantity of its constituents. It requires considerable experience and the most conscientious and scrupulous care to obtain reliable results. Of the wet way, by weight, the general steps may be thus stated: 1. Weigh the body; 2. Dissolve it chemically; 3. Precipitate and wash; 4. Dry, weigh, and calculate.

To take a simple example. A weighed portion of silver coin is acted on by nitric acid by the aid of heat as long as red fumes are given off. To the filtered solution is added pure hydrochloric acid as long as any precipitate falls. This is put on a filter and thoroughly washed with distilled water; the precipitate is then dried and weighed. It consists of chloride of silver, $AgCl$. As the equivalent of chlorine is 35·5 and of silver 108, we can readily calculate the amount of the latter present. Thus, if the precipitate weigh 100 grains, 143·5=108 : : 100 : 82·28 grains of silver.

178. **Volumetric Analysis.**—This is a rapid method, but of comparatively limited application. It depends upon noting the quantity of a solution of a reagent of known strength required entirely to precipitate or neutralise the substance under investigation.

This method will be best understood by the example of the assay of silver coins. The solution used is of common salt, of which 542·74 parts are required to precipitate 1000 parts of silver. The strength of the solution is such that a given measure (French decilitre=3·381 f℥) shall contain 542·74 thousandths of a gramme (15.433 grs.). A second solution of one-tenth of the strength of the first is also prepared. The coin is acted on by nitric acid, which dissolves both the silver and copper. One measure of the solution, of course, precipitates 1000 parts by weight of silver, the copper being unaffected. If any silver remain, an equal measure of the decimal solution is added, which precipitates the $\frac{1}{1000}$ part additionally of silver, and it is thus added as long as any precipitate is observed. As a large quantity of the solution may be prepared at once, the only weighing required is that of the coin, of which so much is taken that it should be almost entirely precipitated by the first addition, if at the lowest allowable standard.

179. **Cupellation** is used only in the separation or assay of gold and silver. A small cup (*cupel*) of bone

ash is prepared; the alloy is enclosed in lead and placed in the cupel, which is exposed to a draught of air at a high temperature. The whole melts, the lead oxydises and soaks into the porous cupel, carrying with it the other metallic oxides, leaving a bright button of silver, or of its alloy with gold, as the case may be. In the latter case, the silver, which must be at least three times the weight of the gold, is afterwards removed by warm nitric acid. When too little silver is added, a portion escapes the action of the acid.

PART III.

CHEMISTRY OF THE ELEMENTS.

TABLE OF THE ELEMENTS.

180. Note. — Those in capitals are important; those in italics, less so; and those in ordinary type, unimportant in Medical Chemistry.

ELEMENT.	SYMBOL.	EQUIVALENT.
OXYGEN,	**O,**	**8·**
HYDROGEN,	**H,**	**1·**
NITROGEN,	**N,**	**14·**
CARBON,	**C,**	**6·**
SULPHUR,	**S,**	**16·**
Selenium,	**Se,**	**40·**
PHOSPHORUS,	**P,**	**31·**
CHLORINE,	**Cl,**	**35·5**
IODINE,	**I,**	**127·**
BROMINE,	**Br,**	**80·**
Fluorine,	**F,**	**19·**
Boron,	**B,**	**11·**
Silicon,	**Si,**	**21·**
POTASSIUM (Kalium),	**K,**	**39·00**
SODIUM (Natrium),	**Na,**	**23·**
Lithium,	**L,**	**7·**
Cœsium,	**Cs,**	**133·**
Rubidium,	**Rb,**	**85·36**

ELEMENT.	SYMBOL.	EQUIVALENT.
Thallium,	T,	204·
Indium,	In,	35·92
BARIUM,	Ba,	68·5
Strontium,	Sr,	43·7
CALCIUM,	Ca,	20·
MAGNESIUM,	Mg,	12·
ALUMINUM,	Al,	13·69
Glucinum,	Gl,	26·50
Zirconium,	Zr,	33·62
Yttrium,	Y,	32·20
Erbium,	E,	?
Terbium,	Tb,	?
Thorium,	Th,	59·59
MANGANESE,	Mn,	27·5
IRON (Ferrum),	Fe,	28·
CHROMIUM,	Cr,	26·
Nickel,	Ni,	29·5
Cobalt,	Co,	29·5
COPPER (Cuprum),	Cu,	31·66
ZINC,	Zn,	32·52
Cadmium,	Cd,	56·
LEAD (Plumbum),	Pb,	103·56
Tin (Stannum),	Sn,	59·
Vanadium,	V,	68·4
Tungsten (Wolfram),	W,	92·
Molybdenum,	Mo,	48·
Tellurium,	Te,	64·5
BISMUTH,	Bi,	210·
ARSENIC,	As,	75·
ANTIMONY (Stibium),	Sb,	122·
Uranium,	U,	60·
Cerium,	Ce,	46·
Lantanum,	Ln,	46·

ELEMENT.	SYMBOL.	EQUIVALENT.
Didymium,	D,	48·
Titanium,	Ti,	25·
Tantalum,	Ta,	68·
Niobium,	Nb,	48·
Mercury (Hydrargyrum),	Hg,	100·
Silver (Argentum),	Ag,	108·
Gold (Aurum),	Au,	98·
Platinum,	Pt,	98·5
Palladium,	Pd,	53·2
Iridium,	Ir,	98·5
Osmium,	Os,	99·5
Rhodium,	R,	52·
Ruthenium,	Ru,	52·

OXYGEN, $O=8$.

181. **Natural Sources.**—It forms about one-fifth of the atmosphere, eight-ninths (by weight) of water; exists in all rocks, most ores, and in all animal and vegetable substances. It is estimated to constitute three-fourths of the matter of the earth.

Preparation.—Heat chlorate of potassa to redness; O is given off and chloride of potassium remains. $KO,ClO_5 = KCl + \overset{\uparrow}{O}6$. The addition of one-fourth, by weight, of black oxide of manganese, MnO_2, or of one-tenth of anhydrous sesquioxide of iron, Fe_2O_3 (*Colcothar*), causes the gas to be evolved more regularly, and at a lower temperature (159); it is then not so pure.

Many other processes have been suggested; the above is almost universally employed. The "oxygenesis" of Messrs. Robbins, a mixture of binoxide of barium, BaO_2, and bichromate of potassa, $KO,2CrO_3$, evolves O, at ordinary temperature, on the addition of a dilute acid. If the compound could be sold at a moderate price, it would do much towards the introduction of this element into medical use.

182. **Manipulation of Gases.** — The *pneumatic trough* consists of a cistern provided with tanks, which are closed above and open below, and are furnished with suitable stopcocks; in these considerable amounts of gases may be stored. To collect smaller quantities, the receiving vessel is filled with water by immersing it so as to allow the air to escape; if its lower edge be kept under water, it will remain filled. It is then placed on a submerged shelf, which may be perforated to admit of the delivery tube of the generating apparatus, or the edge of the jar may project slightly with the same object. The water is sustained in the jar by atmospheric pressure (193); as gases are lighter than water, a bubble admitted into the jar rises to the top, and allows an equal volume of water to fall out, and thus the gas will gradually fill the jar. To transfer gases, it is only necessary to put the mouth of the jar filled with gas slightly below that of one filled with water, beneath the surface of the cistern, and incline the former. The gas will pass up and displace its volume of water from the second jar. Gases soluble in water may be collected over mercury. When very light or very heavy, they may be conveyed to the top or bottom of the jar, and thus *displace* the air, as in the case of hydrogen and carbonic acid.

In the absence of a pneumatic trough, a gas may be collected in a large tumbler over a soup-plate. The tumbler being filled to the brim, a piece of card or thick paper is slid over the mouth; it may then be inverted into the plate filled with water, without the liquid falling out. A bit of wood at the bottom of the plate will serve to keep the edge of the tumbler sufficiently elevated to allow of the introduction of the delivery tube. The plate will be apt to overflow when the water of the tumbler passes out; this can be easily provided against. Where jars are too large to be dipped into the pneumatic trough, they may be filled by suction.

A piece of gum tube is carried to the top of the jar, or floated on the surface of the water by a cork or bit of wood; the air is then drawn out by the lungs or a pump. Where a slight admixture of air is not objectionable, nearly all gases may be collected by simple displacement of the air of the receiving vessel. Large globes of oxygen for the lecture-table are thus filled.

183. **Properties of Oxygen.**— A permanently elastic, inodourous, tasteless, transparent gas; s. g. 1106; water at 60° dissolves 3 p. c.; the most magnetic of gases; combustibles burn in it with increased brilliancy; it is the only supporter of animal life.

Physiological Effects.— It acts as a stimulant, quickening the pulse and respiration, causing after a time fever and death. It converts the venous into arterial blood. Its therapeutic uses have not been satisfactorily determined, except in anæmia, in which Trousseau* recommends highly its inhalation to the extent of six to ten quarts a day. As air contains but one-fifth of its bulk of this vital agent, it is obvious that its inhalation in cases of suspended animation might insure a favourable result in an otherwise hopeless subject.

184. **General Chemical Relations.**— It combines with all the elements except fluorine, and with many of them forms more than one compound (oxide). When the process is unattended by the evolution of light, it is termed *oxidation*; (rusting, fermentation, respiration and decay are included under this head;) when light and heat are feebly evolved, it is known as *slow combustion*, as the glow of a stick of phosphorus or a damp match in air; when with vivid light and heat, we have *ordinary combustion*.

These actions differ only in degree; the heat in oxidation and slow combustion passes off as rapidly as it is formed, and is not sensible to ordinary observation, but may accumulate and pass into ordinary combustion, as in the cases of masses of rusting iron or oiled rags. Oxygen is not essential to combustion, which may take place in chlorine, etc. In the broadest sense, all chemical combination where an element unites on one side, is combustion, although it is generally defined as chemical union attended by *light* and heat.

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* *Clinique Medicale*, t. III., p. 63.

Characters of Oxides.—The lower oxides (*protoxides*, *sesquioxides*) of the *metals* are bases; the higher oxides of the elements generally are acids; the lower oxides of the *non-metallic* elements are acid or neuter. The sesquioxides sometimes combine with protoxides, acting as *quasi* acids.

Thus MnO, protoxide of manganese, is a well marked base, Mn_2O_3 a feeble base, MnO_2 neuter; MnO_3 and Mn_2O_7 are acids. Sulphur, selenium, and tellurium, have also the property when acting as electro-negative constituents of forming both acids and bases. The name *amphigen* (Gr. *amphi*, both, and *gennaō*, I produce) has been applied to this group. Thus we may have KO,AsO_3, arsenite of potassa, an oxygen salt; KS,AsS_3, sulphur salt; $KSe,AsSe_3$, selenium salt; $KTe,AsTe_3$, tellurium salt. The same amphigen exists in the acid and base; an oxygen acid will not unite with a sulphur base. The selenium and tellurium salts are unimportant.

185. **Ozone.**—When electrical sparks are passed through dry oxygen, a small portion, not more than two per cent., is converted into an *allotropic* form (that is, an identical body, but having different properties), called ozone. This change is also produced during the slow combustion of phosphorus in air, or O, and during many chemical changes. Nascent (143) O contains a large proportion of ozone.—*Properties.* It has a peculiar odour resembling fresh-boiled lobster (Houzeaux), is four times as dense as ordinary O (Andrews), and is the most powerful oxidising agent known. At ordinary temperatures it oxidises silver, consumes organic matter, bleaches, and decomposes iodide of potassium. It is converted into ordinary O, at temperatures above 212°. It is present in the atmosphere in varying amounts, being absent in foul localities.—*Tests.* Paper moistened with a mixture of starch and pure iodide of potassium becomes blue by its action, and

sulphate of manganese is decomposed by it, causing paper immersed in a dilute solution of the salt to become brown. These tests are not entirely satisfactory.

Schönbein believes that O exists in two polar conditions, *ozone* and *antozone*, which, when united, form ordinary O. The former is evolved from the higher oxides of chromium, manganese, and lead, the latter from binoxides of hydrogen and barium. These views are strengthened by the recent experiments of Meissner[*] and Baudrimont,[†] but cannot be considered as confirmed. Schönbein, the discoverer of ozone, and who has spent years in its investigation, himself admits that as yet neither ozone nor antozone have been obtained separate from ordinary oxygen. Permanganate of potassa, KO,Mn_2O_7, in solution either alone or with the addition of sulphuric acid, is a convenient source of ozonised air.

HYDROGEN, H=1.

186. **Natural Sources.**—Water, animal and vegetable substances.

Preparation.—By removing O from water, HO; practically by the action of dilute sulphuric acid upon commercial zinc, $Zn+HO,SO_3=ZnO,\overrightarrow{SO_3}+\overset{\uparrow}{H}$.[‡] Being thirteen times lighter than air, it may be collected by displacement, the delivery tube passing to the top of a jar held with the mouth downward.

The self-regulating generator of Dr. Hare is useful in all cases where gases are evolved without the aid of heat. A cylinder has within it a bell-glass, mouth downwards, furnished with a stopcock, and supported on a frame. The zinc in the case of H is suspended or supported within the inner jar; acid water is poured into the outer one; the stopcock being open, it fills both to the same level, and acts upon the zinc. When the air is expelled from the inner jar, the stopcock is closed; the accumulating gas drives the liquid out of the inner jar, and the zinc being no longer acted upon, all action ceases. When the stopcock is opened, gas escapes, the liquid rises by the weight of that in the outer cylinder, and action recommences.

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[*] *Chemical News*, No. 239.

[†] *Ibid.*, No. 334.

[‡] In giving reactions, the *essential* changes only will be represented. In almost all cases the quantity of water present is considerable, but as it appears on both sides of the equation, may be safely omitted. The reaction above expressed would be more accurately $Zn+HO,SO_3+nHO=ZnO,SO_3+nHO+H$, in which nHO represents any fixed quantity of water.

Properties.—A colourless, inodourous, tasteless, transparent, permanently elastic gas; s. g. ·0069 (the lightest of known bodies); inflammable, respirable when diluted with air, but not a supporter of life; water dissolves 2·5 per cent. When mixed with O in nearly atomic proportions and ignited, violent explosion ensues; when the two are burned gradually at a jet, an intense heat is produced (the compound blowpipe). Its *physiological effects* are unimportant.

Chemical Relations.—Is the most electro-positive of the non-metallic bodies, and resembles the metals in many respects. It is replaced by them in combination. When acting as an electro-negative body, it forms *hydrides*. With O, it forms water, HO, and HO_2, binoxide of H.

WATER, HO=9.

187. **Natural Sources.**—The sea, rivers, wells, springs, the atmosphere, organic bodies; is formed during the combustion of hydrogen, and of all bodies containing it.

Water is universally diffused through nature. Even rocks of considerable hardness, as limestone and sandstone, lose a large percentage on drying. The body of man consists of from two-thirds to three-fourths of water; the medusæ or jelly-fish contain over 99 per cent. Potatoes contain 75 per cent.; turnips 90, water-melons 94, and cucumbers 97 per cent. of water. A cubic foot of air at 60°, saturated with moisture, contains 5.756 grains.

Properties. — A transparent, inodourous, colourless, tasteless liquid, solid below 32° F., and boiling at 212° F., at 30 in. Bar. Is compressed $\frac{1}{50.000.000}$ in bulk by the pressure of one atmosphere, 15 pounds. Is taken as the standard of specific gravity of all solids and liquids. One cubic inch weighs, at 60° F., 252·5 grains; is 815 times heavier than air. It is the most universal of all solvents.

188. **Impurities.**—Water always contains air, and frequently carbonic acid in solution. As O is more soluble than N, dissolved air is richer than the atmosphere in the former. It is found exceedingly difficult to obtain water free from air; when it is removed by boiling or the air-pump, it is almost instantly reabsorbed. Rain-water, which is distilled from natural reservoirs, as rivers, lakes, and the sea, is the purest natural form of water, when collected at a distance from habitations. It usually contains nitrates, probably formed during evaporation from the nitrogen and oxygen of the air, or from the combination of these elements under the influence of atmospheric electricity. When collected near habitations, it may contain ammonia and organic matter. When rain falls upon the surface of the earth, a portion runs off, and the remainder penetrates. Owing to the inclined position of the strata, or layers of the earth's crust, it may sink to considerable depths, and be exposed to great pressure and increased temperature. It thus, by the aid of dissolved carbonic acid, CO_2, exercises considerable solvent power upon the constituents of the rocks,* and when it issues through natural or artificial openings (springs, wells, etc.), is more or less charged with mineral matter. On exposure to the air and surface drainage, it is further contaminated by organic matter. *Hard* water contains lime in solution, as sulphate, CaO,SO_3, or carbonate, CaO,CO_2. *Sulphur* waters contain sulphuretted hydrogen, HS, probably derived from the decomposition of pyrites; and *mineral* waters various salts, generally with an excess of carbonic acid. Sea-water contains 2·7 per cent. of common salt, $NaCl$; ·04 per cent. of chloride of magnesium, $MgCl$; ·03 of sulphate of magnesia, MgO,SO_3; ·02 of sulphate of

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* The term *rock* is used in its geological sense, to indicate any constituent of the earth's crust, whether hard as granite, or soft as clay.

lime, CaO,SO_3; with smaller proportions of chloride of potassium, KCl; bromide of magnesium, $MgBr$; carbonate of lime, CaO,CO_2; with traces of iodine, ammonia, and silver.

Tests.—Dr. Clark's *soap test* indicates approximately the *hardness* of water. An alcoholic solution of soap is prepared and tested by a solution containing a known quantity of lime. This is added by degrees to the water to be tested until the bubbles formed become persistent. From the quantity of soap solution used the amount of lime in the water is found. *Permanganate of potassa*, KO,Mn_2O_7, indicates the presence of organic matter by the loss of its colour, and according to Dr. Wood,* one grain of crystallised permanganate is decolourised by 5 grains of organic matter. This result can only be considered as an approximation. The presence of *infusoria* does not indicate a high degree of impurity; they are absent in very foul water.

189. **Purification.**—Water, to a certain extent, is purified by *natural agencies;* on escaping into the atmosphere, carbonic acid, CO_2, escapes, and the earthy and metallic carbonates held in solution by that gas are deposited. In certain cases the soluble salts in different streams which meet mutually decompose each other, forming nearly insoluble compounds. (Example: Carbonate of lime and sulphate of iron in the tributaries of the Schuylkill, $FeO,SO_3 + CaO,CO_2 = \underset{\downarrow}{FeO,CO_2} + \underset{\downarrow}{CaO,SO_3}$.)

Thus, river water is freer, on the average, from saline ingredients than that of springs. *Organic matters* partially subside and are consumed by aquatic plants and animals and destroyed by the ozone given off by the former under the influence of sunlight. The small quantity of mineral ingredients in ordinary river water cannot be considered as injurious to health. When water *freezes*, dissolved matters separate, and the water obtained from melted ice (even that formed from sea-water) is pure enough for ordinary purposes. Water is purified *artificially*, (1) By filtration or subsidence which remove suspended matters, as fine particles of sand, mud, etc. Charcoal filters will also remove certain dissolved organic matters (206). (2) By distillation, which gives, when carefully conducted, pure water. 3. By boiling, which disengages carbonic acid, CO_2, and thus forms the deposit of the less soluble carbonates. 4. By the addition of substances which act chemically or mechanically.

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* *Journal Chemical Society*, March, 1863.

Solution of permanganate of potassa, KO,Mn_2O_7, added to water containing organic matter, will purify it rapidly and harmlessly; a very slight pink tinge indicates that all organic matter has disappeared. This may be removed by inserting a clean stick for a few moments. *Finings*, such as gelatine, white of egg, etc., act mechanically by sinking and carrying down fine suspended matter. Alum, in small quantity, combines with organic matter, and, as the compound sinks, carries down suspended particles. Carbonate of soda, NaO,CO_2, chloride of ammonium, NH_4Cl, vegetable astringents and molasses act chemically in decomposing salts of lime, and are used to prevent incrustations in steam-boilers. Citric acid or lemon-juice added to hard water will correct its purgative tendency.

190. Chemical Relations. — Although neutral to test paper, water combines energetically. With acids, it acts as a base, HO,SO_3, and with bases as an acid, KO,HO, with this important difference, that it does not *neutralise* but rather enhances the chemical power of the body. It is indeed the essential medium in chemical combination at ordinary temperatures. It also combines with salts. Its combination is usually attended with evolution of heat, and when combined it cannot be driven out at 212° F. The combinations of water are called *hydrates* (Gr. *hudor*, water).

The anhydrous acids are mostly destitute of chemical action; the same is true of bases, though both greedily take up water (with certain exceptions) and become hydrates. The water of an hydrated acid or base does not usually enter into combination, $KO,HO+HO,SO_3=KO,SO_3+2HO$. While the combination of water is attended with an elevation of temperature, a depression is observed during solution. Thus, when lime is *slaked*, heat is evolved; when Epsom salt is dissolved, the liquid is cooled.

Water of Crystallisation is not chemically combined; it may be driven off, in which case the body loses its crystallised form, but is not chemically changed; water chemically combined, *constituent water*, cannot be removed without decomposition.

Crystallised oxalic acid, HO,C_2O_3+2HO, may have the two equivalents of water of crystallisation driven off, and will recrystallise unchanged; if the basic water be removed and not replaced by a base, it is decomposed into carbonic oxide, CO, and carbonic acid, CO_2.

191. OFFICINAL FORMS.—(*a*) *Aqua.* Natural water, in its purest attainable state; (*b*) *Aqua destillata.* Take 80 pints of water, distil 2 pints and reject; then distil 64 pints.

The term *Aqua*, U. S. P., signifies a *gaseous* or *volatile* body dissolved in water, as *Aqua chlorini*, *Aqua cinnamomi.* *Liquor*, a solution of a *fixed* body, as *Liquor potassæ.*

DEFINITIONS.—*Maceration*, the long-continued soaking of a body in water at from 60° to 90°. *Digestion*, the same in hot water. *Infusion*, subjecting a body for a short time to the action of hot or cold water, or the result of the process, INFUSUM, U. S. P. *Decoction*, boiling a body in water, or the result of the process, DECOCTUM, U. S. P. *Filtration*, separating an insoluble body from a liquid by means of a porous medium; the liquid which passes through is called the *filtrate*. *Edulcoration* or *displacement* pouring upon the solid matter left on the filter a supply of menstruum whereby that remaining in the solid is displaced. *Lixiviation* or *leaching*, pouring water upon a porous solid mass, whereby any soluble matter is washed out, as in making lye from ashes. *Levigation*, rubbing a body to fine powder. *Elutriation*, throwing a powder into water; the coarser particles settle first, the finer ones remain suspended, and may be separately collected. *Decantation*, pouring off a liquid from a precipitated solid, or drawing it off with a syphon or pipette (195).

NITROGEN, N=14.

192. **Natural Sources.**—The atmosphere, native nitrates, most animal and many vegetable substances.

Preparation.—By burning PHOSPHORUS in confined air, over water, the oxygen of the air is consumed. Phosphoric acid, PO_5, is formed and dissolved by the water.

Properties.—Generally negative. Is without colour, taste, smell, or poisonous effects. Is permanently elastic, does not support combustion or animal life. S. G. 972. Water dissolves 1·47 p. c.

General Chemical Relations.—Has feeble affinities, and unites directly with but few bodies; indirectly with many, forming compounds of the highest importance. With O forms five compounds: NITROUS OXIDE, NO_1; *Nitric oxide*, NO_2; Nitrous acid, NO_3; *Hyponitric acid*, NO_4; NITRIC ACID, NO_5;—with H, AMMONIA, NH_3. We have also the ATMOSPHERE, a mixture of N and O with other gases and vapours.

THE ATMOSPHERE.

193. **Extent, Density, and Weight.**—Is supposed to extend about 50 miles above the surface of the earth; its density is inversely as the square of the distance from that surface; at 2·7 miles one-half, and 5·4 miles one-fourth, etc. One hundred cubic inches at 30 in. Bar. and 60° F., weigh 30·829 grs. Thirteen cubic feet of air weigh a pound avoirdupois nearly. Air is assumed as the standard of s. g. of all gases and vapours, and is taken as 1000. The weight of 100 cubic inches of any gas may be obtained by multiplying its s. g. by 30·829, the weight of

an equal bulk of air. Thus, 100 c. i. of nitrogen=972× 30·829=29·966 grs.

Pressure. The Barometer.—The pressure of the atmosphere is due to its weight, and is, on the average, at the level of the sea, 15 lbs. to the square inch,= to a column of water 34 feet, or of mercury 30 in. high. The *mercurial barometer* is a tube about 34 inches long, sealed at its upper end, containing a column of mercury; its lower end is immersed in an open cistern of the same. The mercury is introduced in small portions, and boiled so that all air and moisture are expelled from the tube. When it is inverted, the mercury falls to the point where its weight is balanced by that of the atmosphere, and leaves a vacuum space above it (the Torricellian vacuum). As atmospheric pressure increases, the column is forced up; when it diminishes, the weight of the mercury causes it to fall. These fluctuations are measured by a scale attached to the side of the tube near the upper end of the column.

In accurate observations, corrections must be made for temperature, capillarity, and the varying level of the mercury in the cistern. The *aneroid* barometer consists of a brass box, partially exhausted, with an elastic metallic lid, which latter is connected with an index, and rises or falls with the varying pressure. It is more sensitive and convenient than the mercurial barometer, and sufficiently accurate for ordinary purposes.

194. **Mariotte's Law.**—The volumes of all gases, at the same temperature, are *inversely* as the pressure; their density and elastic force are *directly* as the pressure and *inversely* as the volume.

Thus, a quart of air reduced to a pint has the pressure on its surface doubled; its volume is one-half, and its density twice that of the original. This law, although not absolutely true, is nearly enough so for all practical purposes.

195. Among the instruments which depend upon the physical properties of fluids, may be mentioned the following:

The *syphon*, Fig. 29, used in decantation, is in its simplest form a bent tube, having one leg longer than the other, the length being calculated from the *surface* of the liquid. When filled, and the shorter leg immersed, the liquid in the longer leg drops out, and the pressure of the atmosphere forces up that in the vessel to take its place. When both ends are bent upwards (the Würtemberg syphon), it may be kept constantly filled, and will act as soon as one is immersed a short distance, as that leg then becomes practically shorter than the other, *a b*, Fig. 30.

Fig. 29.

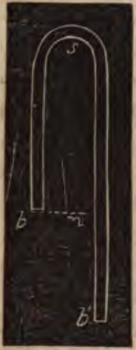


Fig. 30.

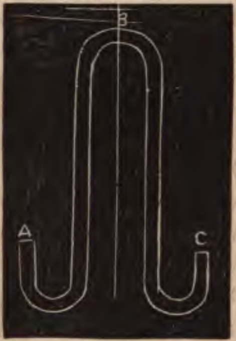


Fig. 31.

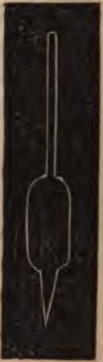
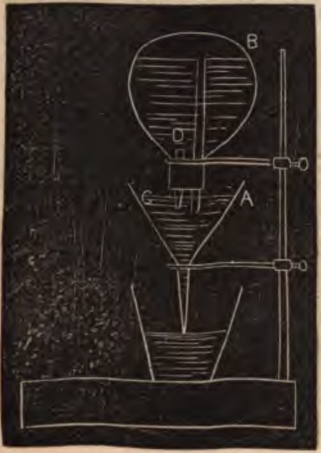


Fig. 32.



The *pipette*, Fig. 31, in its simplest form is a glass tube, which is filled by dipping it into the liquid or by suction. When the finger, placed on top, closes the tube, the liquid is held up by atmospheric pressure; on removing the finger, the liquid drops out. They are often made with bulbs, so as to hold a larger quantity of liquid, and sometimes graduated.

The *continuous wash-bottle*, Fig. 32, has its cork pierced by two tubes, one running to the bottom. When filled with water and inverted, the liquid will flow out of the tube C D, on to the precipitate in the funnel, until it rises so as to close the lower opening of the tube *a b*. It will then cease until the fall of the liquid in the funnel reopens the tube.

Safety tubes are much used in distilling. The simplest consists of a tube, A B, Fig. 33, reaching to the bottom of the vessel, and sealed at its lower end by the contained liquid. Should the delivery tube become obstructed, the pressure of the accumulated gas or vapour in the retort would force the liquid out of the tube and prevent explosion. On the other hand, should sudden condensation occur, causing a partial vacuum in the flask, air will descend the safety tube, and bubbling through the liquid, prevent the regurgitation of that into which the delivery tube dips.

Fig. 33.

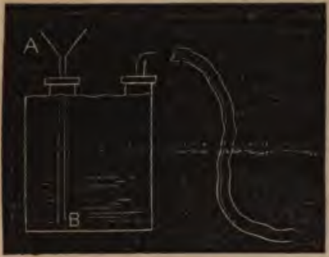
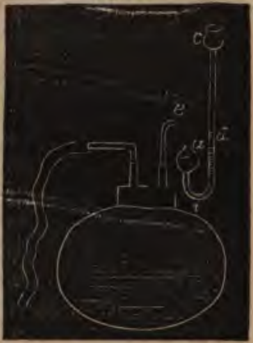
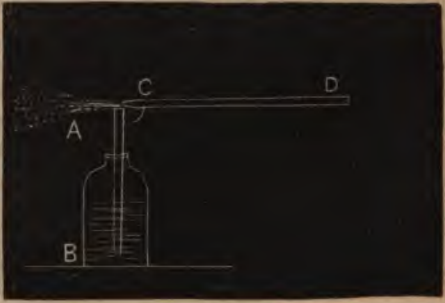


Fig. 34.



Welter's Safety tube, Fig. 34, is used where the contents of the retort are solid, or where, for other reasons, the former cannot be used. Its principle is the same.

Fig. 35.



The Atomiser is an instrument for diffusing the spray of liquids. A vertical tube, A B, dips into the liquid; at right angles to its upper end, and close to it, is a second tube, C D. When air is blown through the horizontal tube, the liquid rises in the vertical tube, overflows and becomes mingled with the blast of air. This is because the pressure on the surface of the column of liquid is less when the current of air is passing over the top of the tube than that of the atmosphere when at rest. The latter, pressing on the surface of the liquid in the containing vessel, forces it up into the tube, where, coming into contact with the blast, it is converted into mist. This instrument is variously constructed. It is used to perfume or deodourise the air of rooms, to apply remedies to the air passages, and to produce local anæsthesia by cold (67).

196. **Composition of the Atmosphere.**—It contains in 100 parts by volume, when dry, 79·10 of N, 20·90 of O, with about ·0004 of carbonic acid, CO_2. There are also constantly present moisture, ammonia, NH_3 (probably as carbonate), *marsh gas*, C_2H_4, and organic matter. The proportions of the first-named elements are nearly invariable (134). The quantity of *ozone* (allotropic oxygen, 185) varies. It appears to be greatest in spring and least in winter, to be absent in foul localities and during certain epidemics, as cholera. Our information on this subject is yet far from reliable. *Carbonic acid*, owing to its low diffusive power (134), sometimes accumulates in undisturbed places, as wells, caverns, etc. The amount of *moisture* constantly varies; is on the average one-half of the amount necessary to saturation. *Ammonia* and marsh gas are present in exceedingly small proportion, the former not exceeding 42 parts in the million. *Organic matter* is most prevalent near inhabited localities and in close rooms. Other gases and vapours may be accidentally present.

197. **Physical Changes.**—The *temperature* of the atmosphere diminishes with the height, about 1° for every

300 feet, although this is subject to considerable variation The *snow line* is highest near the equator. The causes of this fall of temperature are the increased capacity for heat of rarer air, and the more rapid radiation and evaporation at greater elevations. The capacity of the air for *moisture* increases in a geometrical ratio, while the temperature rises in arithmetical ratio. Hence, cooling the air increases its *relative* humidity or dampness. When the aqueous vapour arrives at its temperature of maximum tension (58), it is deposited as fog, rain, snow, etc. The temperature at which moisture is deposited on a cold body is termed the dew point, and is *lower* as the air is *drier*. Instruments for determining the amount of absolute or relative moisture in air are termed *hygrometers* or *psychrometers*.

Air at 32° can absorb $\frac{1}{160}$th of its weight of watery vapour, at 59° $\frac{1}{80}$th, at 86° $\frac{1}{40}$th, and so on, so that for every 27° above 32° its capacity is doubled. The *absolute* humidity of air is the amount of moisture it contains; the *relative* humidity, or dampness, the relation of the former to temperature, or the approach of moisture to condensation. Air when damp conducts better than when dry, and thus produces a sensation of chilliness in cool weather; it also retards evaporation from the surface of the body, and causes oppression and languor in warmer seasons.

Winds are currents of air produced by convection (48). They mostly arise from the unequal heating of the earth's surface, owing to changes of season, of day and night, the obliquity of the sun's rays, and the different absorbing power and specific heat of the materials of the earth's crust (72).

198. **Chemical Changes.**—Combustion and respiration consume the oxygen, and replace it with an equivalent amount of carbonic acid, CO_2; also watery vapour, HO. There is constantly given off from the lungs, skins, and emunctories of animals various excreta, and from decomposing offal a notable proportion of organic matter. When

the processes of nature are not restricted, these are rapidly diffused (134), assimilated, and rendered harmless by the vegetable kingdom (156) and atmospheric ozone. Accumulated, effete, and decomposing organic matter is the most fertile source of disease, and favours the spread of epidemics and contagious disorders. Typhus and cholera are striking examples.

The prevalence of fevers and the exanthemata during the winter, when dwellings are kept closed, and water less freely used, and their comparative rarity during the summer, can be seen by inspecting the bills of mortality of any large city. We have not any satisfactory and convenient test for the amount of organic impurity in the air. The sense of smell is sufficient, when it is considerable in quantity, to warn us of its presence, and hence the uselessness of mere deodourisers or disguisers of filth. Dr. Angus Smith's *air-test* consists of a standard solution of permanganate of potassa, KO,Mn_2O_7, through which the air is drawn. The greater its impurity, the less bulk required to remove the pink colour of the permanganate. The ratio of the quantities of air required was, in one series of experiments, as follows: High ground, 30 miles from Manchester, 176; open street in the town, 72–76; near dirty houses, 44; closely-packed railroad-car, 8.[*] The permanganate solution is decolourised by other reducing agents, as sulphurous acid, SO_2, and sulphuretted hydrogen, HS. These should be intercepted before drawing the air through the permanganate.

The microscope detects in the dust of rooms various excrementatious matter, as exuviæ of animals, portions of clothing, food, and in hospitals epithelial cells and lint charged with organic corpuscles.[†] If the air of a crowded apartment be passed through water, the solution acquires a disgusting smell, and rapidly putrefies.

199. **Antiseptics, Deodourisers, Disinfectants.** — These terms are loosely used and often confounded. *Antiseptics* are processes or bodies which prevent or retard putrefaction or decay, such as drying and the use of common salt, which act by removing moisture; various chemical compounds, as creosote, carbolic acid, chloride of zinc,

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[*] *Athenæum*, June 12, 1858, BRANDE & TAYLOR, Am. ed., p. 151.

[†] CONDY *on Air and Water*, p. 75.

corrosive sublimate, etc., which coagulate the putrescible matters; sulphurous acid, and the sulphites, which check fermentation and putrefaction, and act as oxidisers. *Deodourisers* remove offensive odours, generally by abstracting hydrogen. Fumigations with tar, vinegar, camphor, aromatic weeds and herbs, and the like, only disguise the offensive matter. *Disinfectants* are supposed to prevent the propagation of disease. The most efficient are a high temperature, say 240°, and thorough cleansing. Antiseptics and deodourisers may act indirectly by preventing fermentation in organic matter, or by chemically destroying it. The malarious miasm is destroyed or suspended at 32°.

It should be remembered that while offensive odours warn us of the presence of injurious organic matter, they may not themselves be the cause, or aids of the spread of disease. Sulphuretted hydrogen, HS, phosphoretted hydrogen, PH_3, and ammonia, NH_3, are, when evolved in the laboratory and largely diluted, nearly innocuous, and when accompanying the complex organic substances resulting from decay, only warn us of their presence. Chlorine and ozone will remove their hydrogen, and thus the smell; but unless they be in considerable quantity, the organic matter may remain. The miasm of cholera, malarious fevers, etc., is imperceptible to the senses. It is probable that, after temperature and cleanliness (including ventilation), ozone is the best disinfectant. It is given off indirectly during the action of *chlorine*, and from the permanganates. *Sulphurous* acid, SO_2, from burning sulphur, will check fermentation, and is therefore recommended by high authority.* Carbolic acid is more manageable, and *perhaps* equally efficient.†

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* Graham, *Elements of Chemistry*, Am. ed., p. 253.

† Crookes, *Report on the Cattle Plague*. *Chem. News*, No. 339.

200. **Ventilation.** — The products of combustion, respiration, organic decomposition, etc., being of higher temperature than that of the atmosphere, will rise, be diffused, and eventually rendered innoxious. From desire of comfort in cold climates and seasons, and from inattention to cleanliness, this is often prevented. Habitations are closed, clothing but seldom changed, and personal and other impurities allowed to accumulate. Hence results a large increase of disease and mortality. The problem of supplying a proper quantity of fresh air of a proper temperature and moisture to buildings is one difficult of solution. The most simple method of ventilation is to admit fresh air by numerous openings near the floor of the apartment, and allow the heated, foul atmosphere to pass off above. The cooling effect of walls and windows interferes seriously with this plan; the foul air in contact with these colder bodies becomes reduced in temperature below that of the room, and falls to be again supplied to the inmates. If the openings of exit be large, the external air will descend and cool the foul air, besides causing unpleasant draughts. The external air in winter contains so little moisture (196), that on heating it, unless water be artificially supplied, the air of the apartment is rendered injuriously dry. In large buildings artificially heated, the downward system of ventilation in which fresh air is admitted above and the foul air drawn off below by means of *forced* ventilation, is to be preferred. Forced ventilation is brought about by injecting fresh air by cowls, fans, etc., (*plenum* method,) or by aiding its withdrawal by artificial heat in the ventilating shafts, by exhausting cowls, the steam-jet, etc. The limits of this work will not allow of a full discussion of the subject; in each case much must depend upon a knowledge of the laws of heat, and on the part of the adviser, his judgment in their ap-

plication. In private houses the open Franklin stove affords an excellent means of ventilation, but care is required to supply pure fresh air in place of that constantly withdrawn, in such a way as not to cause unpleasant or hurtful draughts.

COMPOUNDS OF NITROGEN WITH OXYGEN.

201. Nitric Acid, $NO_5=54, HO,NO_5=63$.

Prep.—The anhydrous acid is obtained by passing dry chlorine over dry nitrate of silver; it is a white solid, crystallising in the third system and decomposing spontaneously. The hydrated acid is made by the action of sulphuric acid upon nitrate of potassa (or soda), two equivalents of the former being employed for convenience,
$KO,NO_5 + 2(HO,SO_3) = HO,N\overset{\uparrow}{O}_5\overline{+KO,SO_3+HO,SO_3}.\rightarrow$
The latter salt, the *bisulphate of potassa*, remains in the retort.

Prop.—When pure, a colourless, fuming liquid, S. G. 1·522, boiling at 184°, and solid at — 40°. Is highly corrosive. It ordinarily contains *hyponitric acid*, NO_4, which gives to it a reddish colour. The ordinary acid, $4HO,NO_5$, has a S. G. of 142, and distils at 250°. The latter is the officinal acid, and that usually employed in the arts.

Chem. Rel.—Is a powerful oxydising agent, capable of causing combustion; it generally yields 3 eq. of O, leaving NO_2, which passing into the air gives orange-coloured fumes of NO_4. The monohydrated acid, HO,NO_5, or a mixture of the commercial acid, $4HO,NO_5$, with an equal bulk of HO,SO_3, which latter abstracts a portion of water from the former, has a peculiar action on certain organic bodies, as cotton, starch, and glycerine. It removes a part of their hydrogen, replacing it with NO_4, forming explosive compounds. The ordinary or dilute acid converts starch and sugar into oxalic acid. These changes will be further considered under ORGANIC CHEMISTRY.

Nitric acid acts on the metals in three ways: (1) When concentrated, is itself in part decomposed, $Cu_3 + 4(HO,NO_5)=3(CuO,NO_5)+N\overset{\uparrow}{O}_2+4HO.\rightarrow$ (2) When dilute, the metal takes ox$\vec{y}$gen from the water, $Zn+HO,NO_5=ZnO,N\vec{O}_5+\overset{\uparrow}{H}$. Only the more easily oxydised metals are affected in the latter case, and ammonia is formed as a secondary product. (3) When the metal does not form a basic oxide, as tin or antimony, it raises it to its highest oxide (SnO_2,SbO_5), and *generally* converts the lower oxides of the metals into the higher. The slightly diluted commercial acid acts more readily on the metals than when concentrated. It forms nitrates, all of which are soluble and deflagrate with combustibles. Those of potassa, KO,NO_5, sesquioxide of iron, $Fe_2O_3,3NO_5$, teroxide of bismuth, $BiO_3,3NO_5$, and protoxide of mercury, HgO,NO_5, are officinal. It may contain sulphuric or hydrochloric acids, iron, or, when made from nitrate of soda, iodine. It may be purified by distillation over nitrate of silver.

Tests.—(1) It bleaches a boiling solution of sulphate of indigo; the absence of chlorine or ozone must first be ascertained. (2) Mixed with strong sulphuric acid and a solution of ferrous sulphate, FeO,SO_3, added, a rose or purple tint results. (3) When free, it will, on the addition of hydrochloric acid, dissolve gold leaf. (4) When acting on copper, etc., orange-coloured fumes are evolved. (5) If converted into nitrate of potassa, the characteristics of that salt will be made evident.

Therapeutical and other Effects.—In large doses, an irritant poison. Antidotes: alkalies, soap, chalk, magnesia, etc., mucilaginous and oily drinks and enemeta. Externally, concentrated, a caustic; stains the skin of a permanent yellow; when diluted, stimulant and astringent. Internally, diluted, is tonic, astringent, and is supposed to promote the secretion of bile. Is largely employed in the arts in the preparation of various metallic compounds, analysis, etc.

Incompatibles.—All the nitrates being soluble, the acid is not liable to form precipitates. Hence it only acts when free to decompose the weaker salts, as acetates and carbonates, and will neutralise the basic oxides generally, (potassa, magnesia, oxide of zinc, etc.)

Officinal Forms. (1) *Acidum Nitricum,* s. g. 1·42, $4HO, NO_5$. (2) *Acidum nitricum dilutum,* ℞ *Acid : Nitric* ℥iii, *Aquæ destillatæ* q. s. *ad* Oj. s. g. 1·068. Dose, gtt xx to xl t.d.

202. **Hyponitric Acid** (Nitrous Acid), $NO_4=46$.

Prep.—By mixing two volumes of NO_2 and one of O in an exhausted glass vessel, or by the distillation of dry *nitrate of lead,* $PbO,NO_5=N\overset{\uparrow}{O}_4+PbO+O$. Is formed when NO_2 escapes into the air.

Prop.—At 0°, a colourless liquid; at — 40°, solid; at ordinary temperatures, a ruddy vapour; S. G. 1591, possessing powerful oxydising properties. Supports combustion, but imperfectly; has a suffocating odour. The liquid possesses no acid properties and does not directly combine with bases, but indirectly forms a lead salt, and compounds with certain organic bodies.

203. **Nitrous Acid,** $NO_3=38$.

May be formed by passing through a tube cooled to 0, a mixture of 4 volumes of NO_2 and one of O. It is a greenish liquid, readily decomposed; it does not combine directly with bases, but indirectly forms nitrites, which are soluble in alcohol.

Nitric Oxide, $NO_2=30$, is formed during the deoxidation of nitric acid (201). It is a permanently elastic, colourless, irrespirable gas, s. g. 1038, sparingly soluble in water, supporting the combustion of phosphorus, but not of most ordinary combustibles; it has a strong affinity for O, with which it unites to form NO_4. Is neutral.

204. **Nitrous Oxide**, (Laughing Gas,) $NO=22$.

Prep.—By heating gently nitrate of ammonia, $NH_4O,NO_5=2N\overset{\uparrow}{O}+4H\vec{O}$. The gas should be allowed to stand over water until transparent.

Prop.—A colourless, inodourous, transparent gas, of a sweetish taste; S. G. 1525; water dissolves its own volume. Is liquefied by a pressure of 50 atmospheres at 60°. Supports combustion nearly as well as O; is distinguished from the latter by its sweetish taste and greater solubility. Is neutral.

Physiological Effects.—Causes, when inhaled in moderate quantity, exhilaration, hence the name *laughing-gas;* in larger quantity, is anæsthetic.

205. **Ammonia**, NH_3, or NH_4O, will be considered under the metals.

CARBON, $C=6$.

206. *Natural Sources.*—Native as the diamond, graphite, and impure, as coal; combined in atmospheric carbonic acid, *marsh gas*, and in the native carbonates. Is the essential constituent of organic matter.

Properties.—Vary with the form. (1) *Diamond*, the hardest known body, crystallises in the first system; s. g. 3.5; a good conductor of heat but not of electricity. (2) *Graphite*, plumbago or black lead, soft, crystallises in the 6th system; s. g. 1·8 to 2·1; conducts electricity and has a metallic lustre. (3) *Graphine*, or plumbagine, the deposit in coal-gas retorts; hard and difficult to work; mammillated structure; somewhat metallic lustre; s. g. 1·76; a good conductor of electricity, (used in Bunsen cells.) (4) *Charcoal*, an amorphous body, the properties of which vary with the source. (*a*) *Wood charcoal, Carbo ligni*, U. S. P., is best obtained from the shoots of the willow, previously dried and distilled at a moderate heat. Is a shining, black, hygroscopic powder, without taste or smell; has from its extent of surface great powers of absorbing and condensing gases, thus promoting their combination; hence its power as a deodouriser.

Dr. Stenhouse has shown that small animals imbedded in powdered charcoal rapidly decay without offensive odours being evident. The offensive matters from sewers are easily intercepted and consumed by dry charcoal filters. Charcoal poultices absorb and render inoffensive purulent discharges. This action is due to the condensation of the oxygen of the air in the pores of the charcoal at the same time with that of the effluviæ. By boiling charcoal with $\frac{1}{20}$th of its weight of bichloride of platinum, $PtCl_2$, its power of condensation is much increased. Wood thoroughly dried yields 25 per cent. of charcoal; green wood much less, its carbon passing off as tar, acetic acid, and wood spirit.

(*b*) *Animal Charcoal.* — Obtained by charring bones, *Carbo animalis*, the best by charring blood with pearlash. It is more dense than the last variety, and possesses remarkable powers of absorbing vegetable colouring and bitter principles. By digesting *Carbo animalis* with muriatic acid, U. S. P., each ℥xii previously diluted with ℥xii of water for two days and then washing the residue, the phosphate of lime of the bones is removed and the *Carbo animalis purificatus*, U. S. P., is obtained.

Animal charcoal will remove the colour from most organic solutions. It also absorbs all vegetable bitters except *picric acid;* but yields most of them again to boiling alcohol. It is an antidote to all vegetable and animal poisons, but requires to be given in large quantity and care taken that excess of acid is not present.

(*c*) *Lampblack* is the soot of combustibles containing an excess of carbon; is usually made from coal-tar. It has less lustre than the other varieties of charcoal, is much less dense, and has but little antiseptic or decolourising power.

(*d*) *Coal* is fossil wood; *peat* and lignite are transition forms. Coke is carbon obtained by driving off the volatile matters from bituminous coal, as in gas-making.

207. *General Properties of Carbon.*—It is dimorphous, insoluble in all menstrua, fused and volatilised only in the voltaic arc; is not affected by chemical agents as ordinary temperatures. (Animal charcoal in chlorine water is slowly consumed by the nascent oxygen.) Its combustibility varies with the variety; wood charred at a moderate temperature sometimes ignites spontaneously, while graphite and the diamond are difficult to burn.

Gen. Chem. Relations.—At high temperatures it is the most powerful of reducing agents, owing to its affinity for O. It forms with the metals *carbides*, as cast-iron, and unites, as a general rule indirectly, with other elements. It forms with O **Carbonic Acid**, CO_2, *Carbonic oxide*, CO, *Oxalic acid*, HO,C_2O_3, and croconic, metallic, and rhodizonic acids. Its compounds with H are considered under Organic Chemistry, except those named below. With N it forms the important *quasi* element CYANOGEN, C_2N.

CARBON AND OXYGEN.

208. **Carbonic Acid**, (*fixed air, choke damp*,) $CO_2=22$.

Natural Sources.—The atmosphere, the native carbonates. Is formed during respiration and combustion.

Prep.—On the large scale, by adding SULPHURIC ACID, HO,SO_3, to powdered chalk or marble, $CaO,CO_2+HO,SO_3=CaO,\underset{\downarrow}{SO_3}+\overset{\uparrow}{H}O+\overset{\uparrow}{C}O_2$. In the laboratory, by replacing the sulphuric by MURIATIC acid, which leaves no insoluble residue. $CaO,CO_2+HCl=CaCl+\overset{\uparrow}{H}O+\overset{\uparrow}{C}O_2$. It may be collected by *displacement* (183$\overset{\rightarrow}{)}$.

Prop. — A colourless, inodourous, transparent gas, s. g. 1529, liquid under 28 atmospheres at 32°, and solid at—72°; is incombustible, extinguishes flame, does not support life, but is not poisonous when diluted. It constitutes the *after* or *choke* damp of the miner, and frequently accumulates in old wells and in depressed spots in volcanic districts (Upas Valley). Water dissolves its own volume, and when charged under pressure of 5 atmospheres acquires a pungent taste, reddens litmus and forms an agreeable drink useful in erethism of the stomach — AQUA ACIDI CARBONICI, *Mineral water.* Fermented drinks owe their sparkling and pungent qualities to this gas. It is also the agent in the *raising* of bread.

General Chemical Relations. — It reddens litmus and combines with bases to form the *carbonates*, most of which are insoluble; those of *potassa, soda, lithia, lime, magnesia, iron, lead,* and *zinc* are officinal. Owing to its volatile character, it is readily displaced, being driven out of combination by all acids except the HYDROCYANIC, HCy. Under favourable circumstances it shows great power as an acid, decomposing rocks and playing an important part in the economy of nature. The carbonates and bicarbonates of the alkalies have an alkaline reaction. A carbonate is known by its effervescing when treated with hydrochloric acid, the gas evolved being inodourous.

Medical Effects. — Has been applied locally as a sedative; swallowed in solution, it forms a grateful drink in fevers, and allays thirst and checks vomiting. Inhaled, it rapidly causes insensibility, the treatment being exposure to the fresh air, dashing with cold water, frictions, and in extreme cases artificial respiration. Its presence in wells is made evident by lowering a candle into the suspected locality; the presence of an irrespirable gas will extinguish it. It may be removed by causing draughts of air, by burning straw, or by throwing down water, or better, mixed lime and water. Recent experiments seem to show that when inhaled largely diluted, it is innoxious, an air containing twenty-five per cent. having been supplied to a bird without injuring it.*

209. **Carbonic Oxide, $CO=14$.**

Preparation. — Is formed when C is burned with an insufficient supply of O, the CO_2 formed at first being deoxidised by incandescent carbon above. It is best made by pouring an excess of HO,SO_3 on powdered FERROCYANIDE OF POTASSIUM, K_2Cy_3Fe.†

Properties. — A transparent, colourless, inodourous, permanently elastic gas, burning with a feeble blue flame, producing CO_2; S. G. 968; water absorbs 2·5 per cent. It is a narcotic poison. It frequently escapes from stoves, the treatment, that indicated under CO_2. It is chemically neutral and unimportant.

210. **Oxalic Acid, $HO,C_2O_3+2HO=63$.**

Preparation.—By the action of nitric acid upon starch or cane sugar, or of alkalies upon sawdust.† It exists in combination in certain plants (*Oxalis, Rumex, Rheum*).

Properties.—Long, four-sided, oblique prisms, (third system;) of an acid taste and reaction; is soluble in eight parts of water at 60° and its weight of boiling water. Is used for taking out ink-spots and iron-moulds; resembles in appearance EPSOM SALT, and is sometimes swallowed by mistake. It is an irritant poison; the antidote is chalk or whitewash. The 2 eq. of water of crystallisation may be removed without its decomposition, but it cannot exist except in combination with its constituent water (190) or a base. It forms salts containing one, two, or four equivalents of acid.

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* HAMMOND, *Hygiene*, p. 153.

† The reactions involved are omitted, being complex and comparatively unimportant.

Test.—With a lime salt, or lime-water, gives a white precipitate; with nitrate of silver, also a white precipitate which explodes slightly when dried and heated. Many of the oxalates become carbonates when heated to redness.

211. HYDRO-CARBONS.—The compounds of C and H are exceedingly numerous; the following are generally considered under the head of INORGANIC CHEMISTRY. (1) *Light carburetted hydrogen*, C_2H_4, marsh gas, *fire* damp, a constant product of decomposing vegetable matter, and obtained artificially by the dry distillation of the acetates. It is always present in the atmosphere. It is a colourless, transparent, inodourous, inflammable, permanently elastic gas, not very poisonous; s. g. 522. Water dissolves 0·039 per cent. (2) *Olefiant gas*, Ethylene, C_4H_4, obtained by the action of HO,SO_3 upon alcohol, resembles the former, but is liquefied by cold and pressure; has a faint ethereal odour, and is a narcotic poison; has a s. g. 967, and burns with a brilliant white flame. Water dissolves 0·161 per cent. *Coal gas* is a mixture of the above with the vapours of other hydrocarbons.

In making illuminating gas, the coal is distilled in iron or clay retorts; the tar and ammonia which accompany the gas are condensed and absorbed in the *hydraulic main*, *jet washers*, and *condensers*; the cyanogen, C_2N, carbonic acid, and sulphur compounds are removed by lime or moist oxide of iron. Wood, resin, wax, oil, etc., yield illuminating gas when distilled.

212. **Nature and Structure of Flame.**—By flame is understood volatile matter burning; pure flame gives but a feeble light. Solid matter, heated until it becomes luminous, is said to be *incandescent*, and if not easily oxidised, as platinum, it may remain so for an indefinite period without chemical change. Ordinary flame is hollow because the jet or column of volatile matter can only come in contact with the O of the air on its outer surface. A solid flame is produced by introducing O into

the centre of the burning gas. In a luminous flame, three cones may be distinguished. (1) An inner blue or dark one which consists of gases derived, in the case of an ordinary lamp or candle, from the destructive distillation of the oily matter (cone of generation). (2) A luminous cone (cone of decomposition). In this the compounds of C and H receive a limited supply of O, which having a greater affinity for the H, unites with it; the carbon thus precipitated in the solid form, is rendered incandescent by the intense heat generated by the combination of the O and H, making the flame luminous. (3) An outer cone (cone of complete combustion) of a feeble yellow colour, in which the C, meeting with an abundant supply of O, is burned up. In the middle flame we have a high temperature, deficient supply of O, and abundance of the reducing agents C and H. Hence, many metallic oxides placed in it are deoxidised (reducing flame). At the extremity of the outer flame we have also a high temperature, but an abundance of O, and the reverse effect takes place (oxydising flame). When urged by a jet of air — the blowpipe — the flame is elongated and the intensity of the heat increased. When the gas is mixed with air or O before ignition, no decomposition takes place, no solid matter is deposited, and the flame is blue and feebly luminous. The introduction of a fixed solid body, as lime in the compound blowpipe flame, at once produces a bright light by incandescence. A mixture of air or O with an inflammable gas or vapour is liable to explode, owing to the sudden combination of the whole. The contact of a cold, conducting body may reduce the temperature of the gases below the point of ignition. Hence an explosive mixture may be safely burned at the end of a long, fine, metallic tube. Wire gauze, which may be considered as a number of short tubes of small diameter, acts in this way and a lamp surrounded by it may be safely carried into an atmosphere containing an inflammable gaseous mixture—the *safety lamp*. A jet of mixed gases issuing under pressure is less likely to allow the flame to travel backwards, as the gases move forward rapidly to supply the combustion. When a cold body is introduced into an ordinary flame, the carbon, instead of being burned in the third cone, is deposited; hence, for heating purposes, gas should be previously mixed with air, so as to burn without decomposition.

213. **Carbon and Nitrogen. Cyanogen,** C_2N, resembles in its chemical relations the HALOGENS (223), and will be considered hereafter (235).

SULPHUR, S=16

214. **Natural Sources.**—Occurs native in volcanic districts. Exists in combination in the native sulphides, as iron (FeS_2) and copper pyrites, CuS,Fe_2S_3; galena, PbS, cinnabar, HgS, the native sulphates, as gypsum, CaO,SO_3+2HO, and heavy spar, BaO,SO_3; in organic bodies, in the hair, nails, and horns, the *protein* bodies, and certain volatile oils.

Preparation.—Is obtained by sublimation from its earthy impurities. When the vapour is collected in a cooled vessel, fine crystals are deposited,—*Flowers of sulphur*, SULPHUR SUBLIMATUM, U. S. P. If the vapour is condensed into the liquid state, and cast into moulds, it forms roll sulphur, or brimstone. It is obtained less pure from pyrites, and the *milk of sulphur*, *Lac sulphuris*, SULPHUR PRÆCIPITATUM, U. S. P., is procured by chemical precipitation.

Properties.—In its ordinary form is a lemon-yellow, volatile, inflammable, solid; brittle, tasteless, of a peculiar odour when rubbed. Is a non-conductor of heat and electricity, and gives negative electricity when rubbed. It is dimorphous, crystallising from solution in right rhombic octohedra (3d system), s. g. 2·05, and from fusion in oblique rhombic prisms (4th system), s. g. 1·97. It is insoluble in water, almost so in alcohol; is soluble in *bisulphide of carbon*, CS_2, *benzine*, $C_{12}H_6$, and dichloride of sulphur, S_2Cl. Also in alkaline solutions, but with some chemical change. It melts at 234°, forming a limpid amber-coloured liquid; as the temperature rises, this becomes darker and more viscid; at about 480° is so tenacious as to be poured with difficulty; from 500° to its boiling-point, 788°, becomes thinner, and if allowed to cool, passes through the same conditions. Its vapour is of an orange colour, s. g. 6636. In the state of vapour it combines with finely divided metals, with evolution of light and heat.

Allotropic Modifications. — By the sudden cooling of sulphur heated to about 500°, a dark, plastic, amber-coloured mass is obtained, which gradually assumes the form of ordinary sulphur; it is in great part insoluble in CS_2. *Black sulphur* is obtained by repeating frequently the same process; it probably always contains foreign matter.

Four allotropic modifications of sulphur are now admitted: 1. Common or prismatic sulphur, soluble in CS_2; 2. Octohedral sulphur, partially soluble in CS_2; 3. Crummy sulphur, extracted by CS_2, but afterwards insoluble in it; 4. Insoluble sulphur, insoluble in CS_2, and forming the bulk of the soft sulphur prepared as above stated.

General Chemical Relations. — Is an electro-negative body, closely resembling oxygen, forming sulphur bases and acids and neutral sulphides; also compounds with hydrogen resembling HO and HO_2. It combines with oxygen to form seven compounds, only three of which will be considered, namely, SULPHURIC ACID, SO_3, SULPHUROUS ACID, SO_2, and *Hyposulphurous acid*, S_2O_2.

Medical Effects. — Is innoxious; is given internally in skin diseases, gout, and rheumatism; externally is used in vapour or ointment in the same. Dose, ʒj to ʒiij. Is used in the arts for the manufacture of sulphuric acid, and from its ready inflammability in that of matches and gunpowder.

Officinal Forms. — 1. SULPHUR SUBLIMATUM — Commercial flowers of sulphur. 2. SULPHUR LOTUM, Washed sulphur, hot water being used to remove traces of acid from the former. 3. SULPHUR PRÆCIPITATUM, *Lac sulphuris, Milk of sulphur.* Is made by boiling together for two hours ℥xii of sublimed sulphur with ℥xviii of lime previously slaked, and Oxv of water, adding enough of the latter to compensate for evaporation. Bisulphide of calcium and hyposulphite of lime are formed ($3CaO+S_6=2CaS_2\rightarrow+CaO,S_2O_2\rightarrow$). The solution is diluted with an equal bulk of water, and decomposed by muriatic acid, added gradually so long as a precipitate falls ($2CaS_2+CaO,S_2O_2+3HCl=3CaCl\rightarrow+3HO+\underset{\downarrow}{S_6}$). The chloride of calcium is removed by washing. It is a milky white powder, having a peculiar odour. Is more easily suspended in water than the other officinal forms, hence used in the preparation of hair-washes. All the forms of sulphur should be entirely volatilised by heat, and the two last-named devoid of acid reaction. The UNGUENTUM SULPHURIS, U. S. P., contains one part of S to two of lard.

SULPHUR AND OXYGEN.

215. Sulphuric Acid, $SO_3=40$—$HO,SO_3=49$.

Prep. — (1) *Anhydrous*, is obtained by distilling the *Nordhausen* acid; is in white, silky prisms, melting at 65°, boiling at 110°; attracts water greedily. (2) *Nordhausen* or fuming oil of vitriol, $HO,2SO_3$, is made by distilling dried green vitriol $(4(FeO,SO_3+HO)=2Fe_2O_3+2SO_2+HO,2SO_3+3HO)$. Is a dark, fuming, corrosive liquid, s. g. 1·9; hissing when dropped into water; is too impure for internal administration.

3. SULPHURIC ACID, *oil of vitriol*, ACIDUM SULPHURICUM, U. S. P. Into a leaden chamber are introduced *sulphurous acid*, SO_2, obtained by burning S, nitric acid, and steam; or the floor of the chamber is covered with a stratum of water. When the water becomes sufficiently charged with acid, it is drawn off, concentrated in leaden pans, and afterwards in a platinum still. The following reaction is approximate: (1) $SO_2+HO,NO_5=SO_3+HO+NO_4$; (2) $2SO_2+NO_4=2SO_3+NO_2$; (3) $NO_2+O_2=NO_4$, and so continuously, the NO_2 receiving O_2 from the air of the chamber to form NO_4, which again parts with it to the SO_2, becoming reduced to NO_2. Commercial oil of vitriol, HO,SO_3, is a heavy, corrosive oily liquid, s. g. 1·845. It is the most powerful of the acids, chars and destroys organic matter. Attracts moisture; hence is used as a desiccating agent, and must be kept in tight glass-stopped bottles. When mixed with excess of water, the elevation of temperature is enough to boil the latter.

A straw or small bit of stick will render a whole carboy of acid black; the carbon is merely diffused, and may be separated by filtration through gun-cotton. By mixing 2 vols. of HO,SO_3 and 1 of HO, and allowing the mixture to cool, a terhydrate, $3HO,SO_3$, is obtained, which will convert paper into a parchment-like body, contracting it in all its dimensions, and increasing its strength sixfold.

Medical Effects.—Concentrated or in large doses, an irritant poison; antidote: magnesia or other neutralising bodies, given in milk; water is inadmissible on account of the heat developed by its admixture. Externally a caustic; internally, diluted, tonic, astringent and refrigerant. It is *incompatible*, when *free*, with all alkalies and alkaline earths, and the salts of the weaker acids; when *combined*, with the soluble salts of baryta, strontia, and lead.

Officinal Forms.—ACIDUM SULPHURICUM; S. G. 1·843. Should be entirely volatilised by strong heat, and when diluted with distilled water should not be coloured by SULPHYDRIC ACID, HS (217). ACIDUM SULPHURICUM DILUTUM, S. G. 1·082, contains ℥ij to the Oj. ACIDUM SULPHURICUM AROMATICUM—*Elixir of vitriol*, is made by preparing a pint of tincture of ginger ℥j, cinnamon ℥iss, both coarsely powdered, with alcohol, q. s., and adding to this a cooled mixture of ℥vj of ACID. SULPHURIC. and Oj ALCOHOL.

General Chemical Relations.—Forms an extensive series of well-marked salts,—the *sulphates*. Those of Potassa KO, Soda NaO, Magnesia MgO, Ferrous and ferric oxides FeO,Fe_2O_3, Oxide of manganese MnO, Zinc ZnO, Copper CuO, and Mercury HgO, are officinal. It acts on the metals in two ways. (1) When the metal is not easily oxidised, and the acid is concentrated, one equivalent of acid is decomposed, furnishing oxygen to the metal; with the oxide thus formed a second equivalent combines—$Cu+2(HO,SO_3)=CuO,SO_3+SO_2$. (2) When dilute, the metal, if easily oxidised, decomposes the water present—$Zn+HO,SO_3=ZnO,SO_3+H$. The *test* for sulphuric acid is a soluble salt of *baryta*, which gives a dense, white precipitate, insoluble in boiling HO,NO_5.

216. Sulphurous Acid, $SO_2=32$.

Prep.—Is formed when sulphur is burned. Is made by reducing HO,SO_3.

HO,SO_3 may be reduced by copper, mercury, etc. A cheaper plan is to use $\frac{1}{4}$, by weight, of solid sulphur; $2(HO,SO_3)+S=2SO_2$? $3SO_2$
$+2HO$. Powdered charcoal will answer, but the gas is contaminated by CO_2—$2(HO,SO_3)+C=2SO_2+CO_2+2HO$.

Prop.—A colourless gas of a suffocating odour, acid taste and reaction s. g. 2211; it extinguishes flame and is poisonous; it bleaches, and by its affinity for oxygen arrests fermentation and putrefaction; below 14° is a colourless, limpid liquid, and at —105° solid. Water dissolves 50 vols., and acquires the odour and bleaching properties of the gas. A crystalline hydrate is formed at low temperature. Colours removed by SO_2 may be restored by an alkali.

Medical Effects.—Is used internally in solution, and as the sulphites, in zymotic diseases and blood poisoning; also externally in skin diseases.

Officinal Form.—ACIDUM SULPHUROSUM. Is made by passing the gas evolved by the action of powdered charcoal upon HO,SO_3 through distilled water kept cool, nearly to saturation, s. g. about 1·035. It should be kept cool, and is liable to absorb O and become partially converted into HO,SO_3. Dose for internal use, fʒj, largely diluted.

General Chemical Relations.—Forms SULPHITES, of which those of the alkalies are powerful antizymotic and reducing agents. That of *soda* is officinal. *Hyposulphurous* acid, $S_2O_2=48$, is not isolable. The *hyposulphite of soda*, made by digesting sulphur with sulphite of soda, is used to dissolve the salts of silver in photography and electro-plating. It has been used for the same purposes as the sulphite.

SULPHUR AND HYDROGEN.

217. **Sulphuretted Hydrogen**—*Hydrosulphuric* or *sulphydric acid*, $HS=17$.

Prep.—Is formed by the union of its elements when in the *nascent state* (143); they do not combine when free. It is found in native *sulphur waters*, resulting from the decomposition of iron pyrites, FeS_2, and in sewers and other foul localities, where organic matter containing sulphur is decomposing. Under the latter circumstances it is generally combined with ammonia, and accompanied by other volatile products of putrefaction. It is made by the action of dilute HO,SO_3 upon SULPHIDE OF IRON. $FeS+HO,SO_3=FeO,SO_{3\rightarrow}+HS^{\uparrow}$, or when required pure by the reaction of HCl on SbS_3. $SbS_3+3HCl=SbCl_{3\rightarrow}+3HS.^{\uparrow}$

Prop.—A colourless, inflammable gas, of a characteristic odour and acid reaction; s. g. 1747; is liquefied by a pressure of 17 atmospheres at 60°, and is a white solid at —122°. Water absorbs 3 volumes, the solution slowly decomposes, sulphur being deposited. It does not support combustion, and is a narcotic poison.

Medical Effects.—Concentrated, is rapidly fatal; diluted, causes headache, nausea, and prostration. Is instantly decomposed by chlorine or ozone, which latter may be evolved from a solution of permanganate of potassa. Taken internally in the form of native sulphur water, is popular in the treatment of chronic rheumatism, gout, and skin diseases.

Chemical Relations.—Is a *sulphur acid*, combining with sulphur bases to form salts, as KS,HS; NH_4S,HS. It precipitates many of the metals from their solutions, and is one of our most valuable tests. HS_2 is unimportant.

SULPHUR AND CARBON.

218. **Bisulphide of Carbon** (sulpho-carbonic acid), CS_2, made by passing the vapour of sulphur over red-hot carbon, is a volatile, mobile, inflammable liquid, of high refractive power, insoluble in water, s. g. 1·272. It is used in the construction of prisms, and in vulcanising india-rubber. It freely dissolves fatty matters, and ordinary sulphur and phosphorus. Workmen exposed to its vapours are affected with headache, vertigo, hyperæsthesia, and eventually become cachectic, with dimness of sight and hearing, impairment of memory, and loss of sexual power. It has been

used in skin diseases, rheumatism, and enlarged glands. It is a sulphur acid. A protosulphide and sesquisulphide are known.

PHOSPHORUS, P=31.

219. *Natural Sources.*—Organic substances; the native phosphates.

Prep.—On the large scale from bones, in which it exists as *phosphate of lime*, $3CaO,PO_5$, which are: 1. Calcined, to remove animal matter; 2. Digested with HO,SO_3, which combines with *most* of the lime, liberating the greater part of the phosphoric acid, PO_5. This is heated in a close iron retort with charcoal, which combines with the O of the phosphoric acid, forming CO, leaving the phosphorus to distil over.*

Prop.—A soft, translucent solid, of a waxy appearance; is tasteless; has an alliaceous odour. When perfectly pure, is colourless; ordinarily has a reddish tint, which increases with exposure to light; specific gravity, 1·83. It melts at 111·5°, boils at 550°, giving a colourless vapour. May be distilled unchanged. Emits fumes in the air, (chiefly phosphorous acid, PO_3,) which in the dark are luminous; this slow combustion is accompanied by the formation of ozone, and may be prevented by the presence of certain vapours, as ether, turpentine, and naphtha. Very inflammable, taking fire at 114°; burns with the evolution of copious white fumes of phosphoric acid (PO_5). It is insoluble in water and alcohol; soluble in the fixed and volatile oils, in ether, glycerine, and bisulphide of carbon.

Allotropic Modification.—By exposing phosphorus for a long time to light, or for a shorter time to a temperature between 464°–482°, it assumes a red colour, thickens, and becomes opaque. This *amorphous* phosphorus is unaltered in the air, not poisonous; specific gravity 2·14; insoluble in all menstrua; melts and takes fire at 500°. Heated to the boiling-point, in an indifferent gas, becomes again common phosphorus. Three other varieties of phosphorus have been described: the white, the black, and the viscous. According to Hittorf,* phosphorus may be obtained in rhombohedral (6th system) metallic-looking crystals, resembling arsenic, and conducting heat and electricity; s. g. 2·34.

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* The true process and theory are a little more complicated, owing to the existence of superphosphate of lime. The above gives the essential steps of the process and changes.

Medical Effects.—In large dose, an irritant poison of great energy. No direct antidote is known. Evacuate the stomach; give large draughts of cold water containing magnesia in suspension, or one part magnesia and eight of chlorine water.—(DUFLOS.)

Workmen exposed to its vapours are liable to necrosis, particularly of the lower jaw-bone. In medicinal doses, stimulant, diuretic, and aphrodisiac. Is given in solution in oil or glycerine; dose, $\frac{1}{30}$ to $\frac{1}{16}$ of a grain. Is officinal in the U. S. P.

Tests.—P may be recognised by its odour and luminous appearance in the dark. When very small portions are present, they may be taken up by digestion with CS_2, which, on evaporation, will leave the phosphorus finely divided and luminous. A mere trace of P communicates a green colour to the flame of burning H, and gives a characteristic series of green lines in the spectroscope.†

Chem. Relations.—Forms a natural group with N, As and Sb. It combines with some of the metals, as iron, and is not removed by the highest heat of the furnace. With oxygen it forms P_2O, oxyde of P; PO, *hypophosphorous*

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* *Chemical News*, March 23, 1866.

† WŒHLER, DUSART, CHRISTOPHLE, etc. *Chem. News*, June 6, 1863.

acid; PO_3, phosphorous acid; and PO_5, PHOSPHORIC ACID. With H, solid P_2H, liquid PH_2, and gaseous PH_3, phosphides of H. With N and S, unimportant compounds; the latter are five in number, four corresponding to the O compounds, and one PS_{12} unique; they are highly inflammable.

220. Phosphoric Acid, $PO_5=71$.

Prep. — Is formed anhydrous when P is burned in dry air or O. Is then an amorphous white powder, deliquescent and hissing on the contact of water, becoming hydrated. The TERHYDRATE, $3HO,PO_5$, is made by the action of diluted HO,NO_5 on P. It is very sour, not corrosive, does not act on copper or silver, and is not poisonous.

Chem. Relations.—Phosphoric acid possesses the remarkable property of uniting with either one, two, or three equivalents of water or a base, giving rise to three classes of salts of different physical and chemical properties, which however are mutually convertible. The monobasic acid, HO,PO_5, gives rise to the *meta*phosphates; $2HO,PO_5$ to the bibasic, *pyro*phosphates; $3HO,PO_5$ to the tribasic or common phosphates. Three additional varieties have been described.

The series of phosphates of soda, so ably investigated by Graham,* show in a remarkable manner the peculiar *flexibility* of this acid. Thus we have the following list:

Monobasic, NaO,PO_5, Metaphosphate of soda.
Bibasic, { NaO,HO,PO_5, Bipyrophosphate.
$2NaO,PO_5$, Pyrophosphate.
Tribasic, { $NaO,2HO,PO_5$, Acid phosphate (exists in the urine).
$2NaO,HO,PO_5$, Common phosphate (officinal).
$3NaO,PO_5$, Subphosphate.

Each variety, in case of double decomposition, continues with the same amount of the new base as it previously possessed. Thus $AgO,NO_5+NaO,PO_5=AgO,\underset{\downarrow}{PO_5}+NaO,NO_5\rightarrow$; $2(AgO,NO_5)$

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* *Elements of Chemistry*, Am. ed., p. 321.

$+2NaO,PO_5=2AgO,\underset{\downarrow}{PO_5}+2(NaO,NO_5)_{\rightarrow}$; $3(AgO,NO_5)+2NaO,HO,PO_5=3AgO,\underset{\downarrow}{PO_5}+2(NaO,NO_5)_{\rightarrow}+HO,NO_{5\rightarrow}$. The tribasic variety may be converted into bibasic and this into monobasic by the application of heat, or the process may be reversed by long boiling with water.

Officinal Forms. — ACIDUM PHOSPHORICUM GLACIALE, glacial phosphoric acid, is HO,PO_5; the ACIDUM PHOSPHORICUM DILUTUM, s. g. 1·056, contains $3HO,PO_5$. The acid is tonic and refrigerant. The PHOSPHATES are administered in certain cases of defective nutrition.

Phosphoric acid should give no precipitate with nitrate of silver or chloride of barium (absence of HO,SO_3, or HCl); should not be coloured by HS, or NH_4S,HS, (absence of metallic impurity); should not corrode a strip of silver, (absence of HO,NO_5); should not affect HgCl, (absence of PO_3).

Phosphorous acid, PO_3, formed during the slow combustion of P, is unimportant in medical chemistry.

221. **Hypophosphorous Acid,** not isolable, $HO,PO+2HO=66$.—Is formed when P is boiled with an alkali or alkaline earth, phosphuretted hydrogen being given off. $3(CaO,HO)+P_4=3(CaO,PO)_{\rightarrow}+PH_3^{\uparrow}$ (approximately). The hydrated acid is a syrupy liquid, easily decomposed, a powerful reducing agent. The *Hypophosphites* have been used in tuberculous cachexia, impotence, etc. Oxide of P (P_2O is unimportant) is supposed by some to be merely allotropic P.

222. **Phosphuretted Hydrogen,** which results from the union of its elements when in the nascent state, is given off during the manufacture of the hypophosphites, or when CaP is thrown into water. It is a mixture of the solid P_2H, liquid PH_2, and gaseous PH_3; it is spontaneously inflammable, a property which it loses when mixed with a small quantity of ether or turpentine, and which is due to the presence of PH_2. It has a garlicky odour, and is poisonous; it is decomposed by Cl and ozone.

CHLORINE, $Cl=35{\cdot}5$.

223. *Nat. Sources.*—Common salt; the native chlorides.

Prep.—(1) By gently heating 4 parts of *hydrochloric* acid, HCl, with one of *binoxide of manganese*, MnO_2. $MnO_2+2HCl=MnCl_{\rightarrow}+2HO^{\uparrow}+Cl^{\rightarrow}$. (2) By the action of dilute acids on *chloride of lime* (bleaching salt), $\overline{CaO,ClO+CaCl}+2(HO,SO_3)=2(CaO,\underset{\downarrow}{SO_3})+2HO^{\rightarrow}+Cl_2^{\uparrow}$. The gas may be collected by displacement

Prop.—A heavy greenish yellow gas, of a suffocating odour, s. g. 2470; water absorbs two vols. (AQUA CHLORINII, U. S. P.) It supports combustion, but is fatal to animal life. By cold and a pressure of 4 atmospheres, becomes a bright, yellow, limpid liquid, s. g. 1·33; has not been obtained solid. It is a powerful deodouriser and bleacher of organic colours (except carbon). Colours removed by chlorine cannot be restored.

Med. Effects.—Even when diluted, chlorine causes spasm of the glottis, and, if inhaled, great irritation of the air passages and congestion of the lungs. Some relief is afforded by the inhalation of alcohol or ether. Much diluted, has been inhaled in aphonia and chronic bronchitis, and might be useful in the case of metallic foreign bodies in the air passages, which resist ordinary surgical measures for extraction, causing their gradual conversion into soluble chlorides. It is given internally in solution in scarlatina, diphtheria, and other anginose affections.

Its solution in water is *officinal* as AQUA CHLORINII, and is prepared by passing a current of *washed* chlorine into distilled water, in a large bottle loosely plugged with cotton, agitating the liquid from time to time until saturated. Chlorine water has a yellowish colour and the odour of the gas; is apt to decompose, forming HCl and

O; it should be kept in a cool place excluded from the light; it contains ClO and ClO_7.

224. *Gen. Chem. Relations.*—Chlorine is the type of the HALOGENS (salt-generators), a group of highly electro-negative bodies, having a feeble affinity for O, but an energetic one for H and the metals; so much so that these bodies are never found uncombined in nature. The other Halogens are Bromine Br, Iodine I, and Fluorine F. The members of the *Cyanogen* group, although compound bodies, act as halogens, and are conveniently studied in connection with them. Their compounds, except those of F, are mostly soluble, and are obtained directly or indirectly from the sea. The compounds of the halogens with H are *acids* (hydrogen acids, hydracids); with the metals they combine *directly* to form *salts* (Ex., $NaCl$—common salt), which are simpler in constitution than the *amphide* salts (184), being binary compounds. When a *hydracid* is added to an *oxygen base*, water and a haloid salt result. $AgO+HCl=\underset{\downarrow}{AgCl}+HO_{\rightarrow}$; an *oxygen acid*, added to a *haloid salt*, gives an *oxy-salt* and *hydracid*, $NaCl+HO,SO_3=NaO,SO_3\rightarrow+HCl^{\uparrow}$; an *oxy-salt*, reacting with a *haloid salt*, yields new compounds of the same type, $AgO,NO_5+NaCl=\underset{\downarrow}{AgCl}+NaO,NO_5\rightarrow$. The deodourising and bleaching powers of Cl are due to its affinity for H; ozone is probably set free as a secondary product in some cases. The combustion of a taper or other hydrocarbon in Cl is due to the combination of the latter with the H of the former.

So energetic are the affinities of Cl for H and the metals, that a paper dipped in oil of turpentine will give rise to a spontaneous flash of light, HCl being formed and the carbon deposited in a dense, black cloud. Most of the metals in leaf or powder burn spontaneously, forming chlorides. P also combines at ordinary temperatures, forming PCl_5, but the flame is feeble, owing to the absence of solid matter (212).

Tests.—When free, its odour and bleaching properties; either combined or free, gives, with AgO,NO_5, a white, curdy precipitate of $AgCl$, insoluble in cold or boiling HO,NO_5, soluble in ammonia, and blackening on exposure to light.

225. **Chlorine and Oxygen.**—These elements do not combine directly, and their compounds are unstable. They are Perchloric acid, HO,ClO_7, not isolable; CHLORIC ACID, HO,ClO_5; Hypochloric acid, ClO_4; Chlorous acid, ClO_3; and HYPOCHLOROUS ACID, ClO.

226. **Chloric Acid,** $HO,ClO_5=85$.

Prep.—By passing a current of Cl into hot caustic potassa, KO,HO,—chlorate of potassa, KO,ClO_5, and chloride of potassium are formed. $6(KO,HO)+Cl_6=KO,ClO_{5\rightarrow}+5KCl_{\rightarrow}$. The hydrated acid is obtained by decomposing chlorate of baryta, BaO,ClO_5; by diluted HO,SO_3, $BaO,SO_3\downarrow+nHO,ClO_{5\rightarrow}$ result. The solution is concentrated by evaporation in vacuo. It is a sour liquid, a powerful oxydising agent, and easily decomposed. The *chlorates* are all soluble and deflagrate with combustibles, even more violently than the nitrates; hence their use in pyrotechny. The CHLORATE OF POTASSA, KO,ClO_5, is officinal. By adding strong sulphuric acid to KO,ClO_5, explosive, yellowish vapours of ClO_4 arise. This gas may be liquefied by cold and pressure, and is readily soluble in water. It does not form salts.

227. **Hypochlorous Acid,** $ClO=43{\cdot}5$.—Is a gas resembling chlorine somewhat in colour, odour, and exceeding it in bleaching properties, s. g. 3040; water dissolves 200 vols. It readily decomposes with explosion. The acid itself is unimportant. The *hypochlorites* are largely used as deodourisers and internally in cases where Cl is indicated, and as a convenient extemporaneous source of that element. The *chloride of lime,* so called, contains hypo-

chlorite of lime and chloride of calcium; it is made by passing Cl gradually over hydrate of lime, $2(CaO,HO)+Cl_2=\overline{CaO,ClO+CaCl+2HO}$; from this the other hypochlorites may be obtained by double decomposition.

228. **Chlorine and Hydrogen; Hydrochloric,** or *Muriatic Acid,* $HCl=36{\cdot}5$.

Prep.—By decomposing common salt by HO,SO_3. $NaCl+HO,SO_3=NaO,SO_{3\downarrow}+\overset{\uparrow}{H}Cl$. The gas is passed into a succession of bottles containing water, in which state of solution it is used in practice, ACIDUM MURIATICUM, U. S. P. To obtain it pure, it should be diluted with an equal bulk of water and distilled over chloride of barium, BaCl.

For making a small quantity, the following proportions will be found convenient: 3 of NaCl, 5 of HO,SO_3, and 5 of HO; three of HO are mixed with the HO,SO_3, and when cool poured upon the NaCl in a large retort which is gently heated; the remaining two parts of HO are placed in the receiver to absorb the gas. The gaseous HCl is conveniently obtained on the small scale by boiling an ounce or two of the commercial acid.

Prop.—The gaseous acid is colourless, irrespirable, s. g. 1247; extinguishes flame, and is incombustible. It has a pungent acid odour, and fumes in the air, from its attraction for moisture. By a pressure of 40 atmospheres it condenses into a limpid liquid, s. g. 1·27. Water absorbs 480 vols. and increases in bulk $\frac{1}{3}$. The strongest solution still contains 6 eq. of water; its s. g. is 1·21. The commercial acid contains 8 eq. of HO, s. g. 1·16. It is, when pure, a colourless liquid fuming in the air, sharply acid and corrosive; the commercial acid has a yellowish colour due to iron or sometimes to organic matter. It may be purified by diluting with an equal bulk of water and distilling over chloride of barium.

Chem. Relations.—It is the type of the HYDRACIDS. It acts on easily oxidised metals, as zinc, with the evolution of H, and formation of the chloride; $Zn+HCl=ZnCl_{\rightarrow}+\overset{\uparrow}{H}$. With bases it forms a chloride and water, $AgO+HCl=\underset{\downarrow}{AgCl}+HO\rightarrow$; $F_2O_3,3HO+3HCl=F_2Cl_{3\rightarrow}+6HO$. Two measures of HCl to one of HO,NO_5, form Nitromuriatic acid, *Aqua regia*, which will dissolve gold and platinum. It contains free chlorine and chloronitric acid, NO_2Cl_2, chloronitrous acid, NO_2Cl, and does not keep well.

Med. Effects.—In large doses, HCl is an irritant poison; antidotes, chalk, soap, etc. In moderate doses, gtt x to xx, is used in low fevers, scarlatina, phthisis, dyspepsia, and diphtheria. Is usefully added to gargles, as infusion of cinchona, in the proportion of fʒss or fʒij to f℥vi.

Officinal Forms.—Acidum muriaticum, s. g. 1·160. Acidum muriaticum dilutum, made by adding *aquæ destillatæ*, q. s. to ℥iv. of the acid to make Oj; s.g. 1·038.

Muriatic acid should be colourless, wholly volatilised by heat; when diluted with *aq. destillat.* should yield no precipitate with HS (absence of metals generally), BaCl (absence of HO,SO_3), ammonia in excess (absence of iron), should not dissolve gold-leaf (absence of HO,NO_5).

229. **Acidum Nitromuriaticum.**—℞. *Acid. nitric* ℥iij; *acid. muriatic.* ℥vss; after effervescence has ceased, keep in a glass-stoppered bottle, protected from the light. *Acidum nitromuriaticum dilutum* is made by adding to the former *aq. destillat.* q. s. ad Ojj. Is supposed to act specifically on the liver. Is used internally in the same doses as *acid. muriat.*, and externally in baths.

230. Other Compounds of Cl.—With N it indirectly forms a highly explosive oily liquid, NCl_3 (?); with S, by direct combination, SCl and S_2Cl, both reddish liquids of offensive odour; the latter is used in the vulcanisation of India-rubber. With P, directly, PCl_5, a solid; and indirectly, PCl_3, a liquid.

BROMINE, Br=78·26.

231. *Nat. Sources.*—Sea-water, saline springs, etc., from which it is obtained by a process analogous to that for procuring chlorine. Is officinal as BROMINIUM.

Prop.—Opaque, brownish-red liquid. The only element besides mercury existing in the liquid form at ordinary temperatures; s. g. 2·966; at 19° freezes.

Is volatile at ordinary temperature; has a peculiar odour resembling chlorine, but quite distinct; caustic taste; boils at 145·4°, giving a vapour resembling NO_4; s. g. 5390. Slightly soluble (3 p. c.) in water, more so in alcohol and ether. Is caustic, and stains the skin yellow.

Gen. Chem. Rel.—Resembles *Chlorine;* it does not support combustion, but bleaches. Forms with O, Bromic Acid, HO, BrO_5 (not isolable), and with H, Hydrobromic Acid. Forms compounds (bromides) with N, S, P, Cl, I, and most of the metals, of which the BROMIDE OF POTASSIUM is officinal. The *Bromides* are decomposed by Cl, but Br decomposes the *Iodides.*

Test.—Chlorine water produces an orange-yellow tint in a solution, if bromine be present.

Med. Effects.—In overdose, an irritant poison; antidote, ammonia (Smee). Is used externally, concentrated or in watery solution, as a caustic. Internally is rarely given free, generally as Bromide of Potassium.

IODINE, I=127.

232. *Natural Sources.*—Is widely diffused in nature, being found in sea-water, sea-weeds, sponge, salt-water mollusca, cod-liver oil, mineral springs, in many vegetables, and the native iodides, as iodide of lead. It is obtained commercially from *kelp*, the ashes of sea-weeds, in

which it exists as iodide of sodium. The process is analogous to that for obtaining Cl and Br.

Properties. — Soft bluish-black scales of a metallic lustre. It may be obtained by sublimation in oblique rhomboidal crystals (5th system). It evaporates at common temperatures, having an odour somewhat resembling that of Cl and Br; its taste is hot and acrid; it is irritant when inhaled, and stains the skin of an evanescent yellow; when continually applied, it causes thickening and desquamation of the cuticle. The s. g. of iodine is 4·948; it fuses at 225°, boils at 347°, giving a vapour of a beautiful violet colour, and having a s. g. 8716. It requires 7000 parts of water for solution, which is of a brownish colour. The addition of iodide of potassium renders it freely soluble. It is soluble in 12 parts of alcohol, and freely in ether, glycerine, and benzole.

General Chemical Relations. — Has the general character of the halogens (244). Its affinities are more feeble than those of Cl and Br. It does not bleach, but is a deodouriser. Indirectly, it forms iodic acid, HO,IO_5, the periodic acid, HO,IO_7, the *hydriodic acid*, HI; also compounds with N, S, P, Cl, Br, and the metals. Iodine, hydriodic acid, the iodides of sulphur, potassium, iron, lead, arsenic, and mercury are officinal. The iodide of nitrogen, NHI_2, made by adding ammonia to a strong tincture of iodine, is when dry a black solid, exploding when touched.

Impurities. — Fixed adulterations, as charcoal, plumbago, and black oxide of manganese, remain when the iodine is sublimed. Water, which sometimes exists to the extent of 15 or 20 per cent., may be detected by the scales of iodine adhering to the sides of the bottle, and removed by quicklime. Iodide of cyanogen being more volatile than iodine, rises at the beginning of the sublimation, and condenses on a cold surface in colourless, pungent crystals. *Test.*—Boiled starch yields a deep blue colour; the solutions must be cold, and the iodine *free.* If combined, it may be liberated by HO,NO_5.

Medical Effects.—Is used externally as a counter-irritant and discutient; internally as an alterative. In over-dose, is an irritant poison; *antidote*, boiled starch. The contact of metals in any form should be carefully avoided in administering it.

233. *Officinal Forms:*—

(1) *Iodinium.*

(2) *Tinctura Iodinii* contains ℥j in Oj *alcohol*, or gr j to gtt xxxv. When first made it is decomposed by admixture with water; after a time, hydriodic acid, HI, and other compounds are formed which prevent this. It is generally used externally. Dose, gtt x to xx. The so-called colourless tincture of iodine is made by adding an equal bulk of solution of ammonia (276). It contains iodide of ammonium; explosive iodide of nitrogen might be formed from it (232).

(3) *Tinctura Iodinii Composita* contains ℥ss *Iodinii*, ℥j *Potassii Iodidi*, to Oj *Alcohol.* It may be diluted without change. Dose, gtt x to xxx.

LIQUOR IODINII COMPOSITUS—*Lugol's solution*, contains gr ccclx of *Iodine*, ℥iss *Potass. Iodid.*, in Oj *Aquæ.* The iodine is rendered soluble by the KI. This solution keeps well, and is the best form for internal use. Dose, gtt v to x.

UNGUENTUM IODINII is made by rubbing gr xx *Iodinii*, gr iv *Potass. Iodid.* with ♏vj *Aquæ*, until dissolved; then mixing thoroughly with ℥j *Adipis.* It is a powerful stimulant and discutient, but does not keep well.

UNGUENTUM IODINII COMPOSITUM is prepared in the same way, using gr xv *Iodinii*, gr xxx *Potass. Iodid.*,

♏xxx *Aquæ*, and ℥j *Adipis*. Is somewhat stronger than the former, and keeps better.

ACIDUM HYDRIODICUM DILUTUM is made by passing a current of HS through I, suspended in distilled water, until the color of the I disappears; sulphur is deposited. ℥j *Iodinii*, with q. s. *Aquæ destillatæ* to make ℥vj, are the proportions used. $I + HO + HS = HI_{\rightarrow} + HO_{\rightarrow} + \underset{\downarrow}{S}$. The s.g. of the preparation is 1·112; it contains 10 grs. of I to fʒj. Dose, gtt iv, gradually increased. Effects, those of I.

SULPHURIS IODIDUM, *Iodide of Sulphur*, S_2I; is made by melting together in a glass flask a mixture of ℥iv *Iodinii* and ℥j *Sulphur. sublimat.* It is insoluble in water, soluble in 60 parts of glycerine; entirely volatilised by heat, and decomposed by long boiling in water. Is used externally in chronic skin diseases. The UNG. SULPHURIS IODIDI contains gr xxx to ℥j *Adipis*. It should not be perfumed, as S_2I is decomposed by many volatile oils.

FLUORINE, F=19.

234. *Nat. Sources.*—Fluor spar, CaF, Cryolite, Al_2F_3, 3NaF; it exists in recent bones and the enamel of teeth. Owing to its energetic affinities, has never been satisfactorily isolated. Its only compounds with the non-metallic elements are *Hydrofluoric Acid*, HF, and fluoride of silicon, SiF_3, and fluoride of boron, BF_3.

Hydrofluoric Acid, HF=20.—Is prepared by the action of HO,SO_3 upon powdered fluor spar in a leaden vessel, $CaF + HO,SO_3 = CaO,SO_{3\rightarrow} + \overset{\uparrow}{H}F$. Is a colourless, highly corrosive gas, s. g. 689; below 60°, is a colourless liquid, s. g. 1·06; it has not been frozen. A *hydrate*, 4HO,HF, s. g. 1·16, is made by gradually adding water to this liquid; it boils at 284°, and may be preserved in gutta-percha bottles. It is chiefly used for etching upon glass, which it accomplishes by attacking the *silica* of that substance.

In etching upon glass, the plate is first covered with wax, conveniently by pouring over it a solution of wax in benzine, and allowing the latter to evaporate. The design is then traced through the wax with the point of a needle, and the plate laid, face downwards, upon a leaden trough containing the powdered CaF and HO,SO_3. The gas rises upon the application of a gentle heat, and speedily corrodes the glass where not protected by the wax; the latter may be removed by benzine or oil of turpentine. The liquid acid may be used, but the lines while eaten into the glass are transparent and not easily seen; when the gaseous acid is used, they are rough and translucent.

CYANOGEN, C_2NCy=26.

235. *Prep.*— C and N unite at a high temperature in the presence of a strong base. When a current of N or air is passed over a mixture of charcoal and pearlash heated to redness, *cyanide of potassium*, KCy, is formed, $KO,CO_2+C_4+N=KC_2N_{\rightarrow}+3\overset{\uparrow}{C}O$. It is also formed during the destructive distillation of coal and animal matters, the ammonia formed at the same time acting as the base. It may be obtained free by heating to redness well dried *cyanide of mercury*, HgCy; a portion of the Cy passes over, the mercury volatilises, but is condensed in the cooler part of the retort, and a black body, paracyanogen, C_4N_2, remains. The gas must be collected over mercury.

Prop.— A colourless, neutral gas, of a pungent odour, irritating to the eyes, highly poisonous, inflammable, burning with a peachblossom-coloured flame, s. g. 1806. Water dissolves 4.5 volumes, alcohol 23 volumes. The watery solution rapidly decomposes on exposure to light; is condensed by cold and a pressure of three atmospheres into a colourless, limpid liquid, s. g. 0.9; at —30° is solid.

Chemical Relations.— Although a compound, cyanogen acts as an element. It belongs to the halogens, forming a hydrogen acid, HCy, and cyanides. Its affinities are less energetic than those of Cl, Br, and I; it does not combine directly with H, bleach, nor support combustion, except of the alkali metals, which, when ignited and introduced into it, combine directly, producing their cyanides. It forms a curious and important series of *conjugate* compounds* with S and certain metals, which are not isolable, but have the same chemical relations as Cy. The most important of these are, FERROCYANOGEN, $FeCy_3$, *ferricyanogen*, Fe_2Cy_6, and *sulphocyanogen*, S_2Cy.

With O, it forms a series of acids which exist (except cyanuric Cy_3O_3) only in combination with water or a base; they are *polymeric*—that is, have the same constituents in multiple proportions. HO,CyO, *Cyanic acid;* the cyanate of ammonia is identical or isomeric with UREA. $2HO,Cy_2O_2$, *fulminic acid*; the fulminates are highly explosive; that of mercury is used in percussion-caps and friction-primers. $3HO,Cy_3O_3$, cyanuric acid, and $HO,Cy_3O_3,+2HO$, fulminuric acid.

236. **Hydrocyanic Acid** (*Prussic Acid*), HC_2N, or HCy =27.

Prep.—Anhydrous by passing dry HS over dry *cyanide of silver*, $AgCy+HS=AgS_{\rightarrow}+H\overset{\uparrow}{Cy}$; *diluted* by the reaction of AgCy and $HCl+nHO=Ag\underset{\downarrow}{Cl}+H\underset{\rightarrow}{Cy}+nHO,\rightarrow$ or by the action of dilute sulphuric acid upon ferrocyanide of potassium, K_2FeCy_3. This reaction is complex.

Prop.—Anhydrous, a colourless liquid, s. g. 7058; powerful characteristic odour; solid at 3°, boils at 79°; s. g. vapour 696. Is fearfully poisonous, whether applied to the tongue, the skin, or when inhaled; a single drop placed upon the tongue produces almost instant death. It is feebly acid, and prone to decomposition. The *dilute* acid possesses the same properties in a less degree; it has a warm, acrid taste, and inhaled produces irritation of the nose and fauces.

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* *Conjugate compounds* are those in which the properties differ from those of their constituents in *degree* rather than in kind.

Medical Effects.—In medicinal doses, is sedative and antispasmodic; externally, is applied to allay the itching of prurigo. Dose of the medicinal acid, gtt ij to vj, diluted.

In *poisonous* doses, the effects are, sudden loss of consciousness, difficult and rattling respiration, immobility, and sometimes contraction of the pupils, swelling and stiffness of the neck, and convulsions. In many cases death is almost instantaneous. Where time is allowed for the use of antidotes, *chlorine*, which may be liberated by moistening chloride of lime on a towel with vinegar, is the most efficient. It may be inhaled cautiously, or given internally as chlorine water. Next to chlorine ranks ammonia; a mixture of ferrous sulphate, FeO,SO_3, with ferric sulphate, $Fe_2O_3,3SO_3$, and carbonate of potassa, KO,CO_2, has been used successfully. It converts the poison into inert *Prussian blue*, Fe_4Cfy_3. *Cold affusion to the spine*, and frictions, are also to be employed.

Tests.—When not overpowered by other strong odours, that of HCy is characteristic. 1. *Nitrate of silver* gives a dense white precipitate, insoluble in cold, HO,NO_5, soluble in boiling, HO,NO_5, not blackened on exposure to the light (distinction from AgCl). When well dried it may be decomposed by heat in a tube of hard glass, and the characteristic flame of Cy obtained. 2. *Scheele's.* Add to the suspected solution a few drops of a solution of ferrous sulphate, FeO,SO_3, followed by solution of potassa, KO,HO, a greenish colour will be produced, which darkens on agitation, from the absorption of O. Then add diluted HCl; *Prussian blue*, Fe_4Cfy_3, will remain behind, and may be recognised by its colour and insolubility in dilute acids. 3. *Liebig's.* Add to the suspected solution a few drops of *sulphydrate of ammonia*, NH_4S,HS, sulphocyanide of ammonium will be formed ($NH_4S,HS+HCy+O_2$ (air)$=$ $NH_4S_2Cy+2HO$). This gives a blood-red tinge with the salts of the sesquioxide of iron (ferric salts). Sulphocyanide of potassium, KS_2Cy, exists in the saliva of man, the dog, horse, and sheep;* this fact should be borne in mind in using this test.

These tests may be conveniently applied to the vapour of the acid, as it issues from a complex liquid, by putting the latter in a small jar over which is inverted a watch-glass. Into the latter the test solutions are to be placed. (Taylor.)† The tests should be applied early on account of the volatile and unstable character of the poison. After putrefaction it is found as sulphocyanide of ammonium, which may be dissolved out by alcohol. In order to separate the acid from the complex contents of the stomach, the latter should be acidulated with tartaric acid, and distilled at a temperature not exceeding 178°, the receiver being kept cool by ice.

Officinal Form.—*Acidum Hydrocyanicum dilutum.* Prepared (1) by the action of dilute sulphuric acid upon ferrocyanide of potassium, (K_2Cfy). (2) *Extemporaneously*, by mixing 50½ grs. of *cyanide of silver*, $AgCy$, with ℥i of distilled water, and adding 41 grs. of muriatic acid. When the chloride of silver has subsided, pour off for use; it should be kept in well-stopped bottles, away from the light. It contains *two per cent.* of real acid. *Dose*, gtt i to v. *Scheele's* acid contains 5 per cent. and should never be employed. *Incompatibles*, the alkalies, salts of silver, iron, copper, and mercury; *paregoric.*

237. **Ferrocyanogen**, $FeCy_3, Cfy$, *Ferricyanogen*, Fe_2Cy_6 Cfdy, and *Sulphocyanogen*, S_2Cy. When cyanide of potassium is digested with iron filings, oxygen is absorbed, the iron disappears, and lemon-yellow crystals of *ferrocyanide of potassium*, K_2FeCy_3+3HO or K_2Cfy, may be obtained on evaporation. By passing through a cold dilute solution of K_2Cfy a current of chlorine, the liquid acquires a reddish colour, and on evaporation yields ruby crystals of *ferricyanide* of potassium, $K_3Fe_2Cy_6$, or K_3

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* LEHMANN'S *Physiological Chemistry*, i. 421.

† BRANDE and TAYLOR, Am. ed., 269.

Cfy; $2K_2Cfy+Cl=K_3Cfdy\rightarrow+KCl\rightarrow$. Sulphocyanide of potassium, KS_2Cy or KCsy, is prepared by fusing S with KCy.

Chemical Relations.—These remarkable bodies are members of a group of bodies (argento-cyanogen, platino-cyanogen, cobalto-cyanogen, nitro-prussides) none of which are isolable. They are all electro-negative, and act as halogens, forming H acids (hydroferrocyanic H_2Cfy, hydroferricyanic H_3Cfdy, hydrosulphocyanic HCsy) and salts. The ferrocyanides of potassium and iron are officinal.

The iron in the ferro and ferricyanides has its chemical and to a certain extent its physical properties suspended. It has become electro-negative. It cannot be detected by the usual chemical tests, and the crystals are diamagnetic, that is, are repelled by the magnet, whereas all bodies in which iron exists in its ordinary, or basic, or electro-positive form, are powerfully magnetic.

BORON, B=10·9.

Is an unimportant element belonging to a natural group with carbon and silicon. It exists in boracic acid, BO_3, which is found in certain lagoons in Tuscany, and as **Borax**, *biborate of soda*, $NaO,2BO_3+10HO$, found native in India and California. BO_3 fuses to a transparent glass, its crystalline hydrate, HO,BO_3+2HO, is in transparent pearly scales (5th system), soluble in 25 parts of cold and 3 of boiling water, and in alcohol, to the flame of which it communicates a green colour; it is volatilised at a white heat. It is nearly tasteless, and feebly reddens litmus; at ordinary temperature is the feeblest of the acids, but from its fixed character will decompose the sulphates at a red heat (171).

SILICON, Si=21.

238. Exists combined in nature as SILICA, SiO_3. In this form it is abundantly distributed, silica being found nearly pure as quartz and sand, and combined in clay, granite, feldspar, and many crystallised minerals. It exists also in the stalks and husks of grain, in the ashes of plants, in the hair, and forms the skeletons of infusoria, which, when fossil, constitute polishing slates and powders. The element has been, like boron, obtained in three forms, resembling carbon in its modifications of the diamond, graphite, and lampblack.

Silica, Silicic Acid, SiO_3.—Quartz, flint, agate, chalcedony, etc., are nearly pure varieties of this substance. From its insolubility it possesses no acid reaction, but at a high temperature combines with bases to form the silicates, as glass. Mr. Graham has obtained it in the soluble form by dialysis (128). It has then an acrid taste, and reddens vegetable blues; it speedily assumes the insoluble or *pectised* condition. It may be precipitated from an alkaline silicate as a gelatinous *hydrate* containing a variable proportion of water; it is then soluble in the mineral acids and combines with caustic alkalies. The latter attack the softer forms of glass, abstracting the silica. With F it forms a gaseous fluoride of silicon, SiF_3, which is decomposed by water, yielding silica and hydrofluosilicic acid, $2HF,3SiF_3$. The latter is used in analysis.

THE METALS.

239. *Nat. Sources.*—The less easily oxidised metals, as silver, gold, platinum, copper, and bismuth, are found *native*, that is in the metallic state. Lead, copper, mercury, arsenic, antimony, and iron, zinc and others, occur as sul-

phides. Iron and tin usually occur as oxides. The following occur as oxy-salts: the metals of the alkalies and alkaline earths, as carbonates, sulphates, and silicates; iron as carbonate, zinc as carbonate and silicate; lead as carbonate, sulphate, phosphate, etc. The native chlorides and iodides, except of sodium, are rare.

240. *Extraction.*—Native metals are separated from the surrounding rock or gangue by crushing, the metal being tougher resists, while the rock is powdered; the two are then thrown into water; the metal, by its greater specific gravity, sinks, while the powdered rock remains temporarily suspended and is poured off with the water. When the metal occurs in large masses, these are picked out by hand; when the particles are very fine, they cannot be separated by difference of specific gravity, and are then, in the case of the precious metals, extracted by amalgamation, the action of chlorine or the alkalies, which latter dissolve the quartzy gangue. *Oxides* and oxy-salts are reduced by carbon at a high heat. *Sulphides* are roasted, that is, heated with exposure to air; the S is burned off, and the metal generally remains as oxide.

241. *Properties.*—The metals are all *opaque;* gold in very thin film transmits a greenish light. They are all *insoluble* in menstrua. When attacked by acids, it is not true solution, but chemical compounds are formed. They have a brilliant *lustre;* this is also possessed by C (graphite), I, and some sulphides (galena, pyrites, etc.). They are the best *conductors* of heat and electricity, silver standing first, and bismuth last on the list. Some, as gold, iron, lead, and tin, are highly *malleable;* gold may be beaten into leaves the $\frac{1}{200000}$ of an inch in thickness; bismuth, antimony, and arsenic may be powdered; zinc is malleable or brittle according to the temperature. Their *ductility* or *tenacity* varies. Iron and platinum bear draw-

ing into very fine wire; lead has only $\frac{1}{28}$ the tenacity of the former. Their *specific gravity* varies from lithium, 0·593, the lightest solid body known, to platinum, 21·530, the heaviest. Their *fusing* points vary from —39° mercury to the heat of the compound blowpipe. They are probably all *volatile*, but the following may be distilled: mercury, zinc, cadmium, arsenic, potassium and sodium.

242. *Chem. Relations.*—With each other they form alloys; those with mercury are termed amalgams. They all unite with O, but with varying affinity. Some, as potassium, decompose water at ordinary temperature; others, as iron, at a red heat; others, as silver, gold, and platinum, will only unite by indirect methods. The *protoxides* are strong bases, the *sesquioxides* feeble ones, sometimes acting as acids; the higher oxides are *generally* neuter or acid. The sulphides, chlorides, and iodides generally correspond in their number and the proportion of their constituents to the oxides Ex.: FeO,Fe_2O_3, FeS,Fe_2S_3, $FeCl$, Fe_2Cl_3, etc. As exceptions to this law, we find generally more sulphides than oxides, and fewer chlorides and iodides.

Constitution of Salts.—A salt is the union of an acid with a base, or of a halogen body with a metal (224). Oxygen, sulphur, selenium, and tellurium are the only electro-negative bodies capable of forming both acids and bases. Ex.: KO,AsO_3; KS,AS_3, $KSe,AsSe_3$; $KTe,AsTe_3$; they are termed the amphigen bodies (184). The amphigen must be the same in the acid and base.

Thus, an oxygen acid will not unite with a sulphur base, but decomposes it. $KS+HO,SO_3=KO,SO_3\rightarrow+HS.\uparrow$ Sometimes we have a union of an oxide and a sulphide or chloride, forming an *oxysulphide;* Ex.: $SbO_3,2SbS_3$; or *oxychloride*, as $5SbO_3,SbCl_3$; but these are not salts. The only important amphide salts are those of O and S. It has been proposed to bring all salts under the same constitution, as haloid salts, by assuming the H as the acidifying principle in all acids. Under this *binary* theory of salts, sulphuric acid is H,SO_4, sulphate of potassa K,SO_4, etc., the metals merely replacing the hydrogen of the acid. This theory, although attractive, is incompatible with many well-established chemical facts.

243. **Normal Salts.**—The rule in regard to the constitution of oxy-salts is, that they must contain as many equivalents of *acid* as there are of *oxygen* in the base. Thus, for a *protoxide* one, FeO,SO_3; a *sesqui-* or *ter*-oxide three, $Fe_2O_3,3SO_3$, $BiO_3,3NO_5$. Such salts have been termed *neutral*, but *normal* is preferable, as the salts of the sesquioxides are acid to test-paper. Where a body is chemically indifferent as MnO_2, the term *neuter* is suggested. Where the proportion of acid is not so great as that indicated, a *sub*-salt is formed which generally crystallises imperfectly or not at all, and is in many cases insoluble; $3PbO,C_4H_3O_3$, *tris*-acetate of lead; $2Fe_2O_3,5SO_3$, *sub*-sulphate of sesquioxide of iron.

The student is generally confused, in studying the *sesqui* compounds, by overlooking the fact that the equivalent is doubled. The *proportion* of iron in Fe_2O_3 is $FeO\,1\frac{1}{2}$; but to avoid the half equivalent, the formula is doubled; hence, *two* eq. of a protoxide yield but *one* of a sesquioxide. In *all cases* of reactions of sesqui compounds, *three* equivalents of the reacting body are required. The student will find the study of the reactions given below very useful in overcoming the difficulties of those met with in the chemistry of the metals. They are the types of changes constantly recurring.

1. Protoxide with HCl; $ZnO_{\rightarrow}+HCl=ZnCl_{\rightarrow}+HO_{\rightarrow}$.
2. Sesquioxide with HCl; $Fe_2O_3,3HO+3HCl=Fe_2Cl_{3\rightarrow}+6HO_{\rightarrow}$.
3. Protosalt with alkali; $FeO,SO_3+KO,HO=FeO,\underset{\downarrow}{HO}+KO,SO_{3\rightarrow}$, or $FeCl+KO,HO=FeO,\underset{\downarrow}{HO}+KCl_{\rightarrow}$.

4. The same with an alkaline carbonate; $FeO,SO_3+KO,CO_2=FeO,\underset{\downarrow}{CO_2}+KO,SO_{3\rightarrow}$, or $FeCl+KO,CO_2=FeO,\underset{\downarrow}{CO_2}+KCl_{\rightarrow}$.

5. Sesqui-salt with an alkali; $Fe_2O_3,3SO_3+3(KO,HO)=Fe_2O_3,\underset{\downarrow}{3HO}+3(KO,SO_3)_{\rightarrow}$,* or $Fe_2Cl_3+3(KO,HO)=Fe_2O_3,\underset{\downarrow}{3HO}+3KCl_{\rightarrow}$.

For other important typical reactions, see Chemistry of CHLORINE.

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* The sesqui-salts usually react with alkaline carbonates, as with the caustic alkalies, CO_2 being given off.

General Methods of Preparing Compounds of the Metals.

244. 1. *Oxides* are made by (*a*) direct combination, as in burning zinc; (*b*) by precipitation of a salt by caustic alkali, as in making ferric hydrate, $Fe_2O_3,3HO$ (314); in this case the oxide is generally hydrated. (*c*) By decomposing an oxy-salt, as in making lime from its carbonate or red precipitate from the nitrate of mercury. 2. *Sulphides* are usually found native or formed by direct combination. 3. *Chlorides.* (*a*) By direct combination of the gas or the free chlorine of Aqua regia (228). (*b*) By the action of HCl on an easily oxidised metal, $Zn+HCl=ZnCl_{\rightarrow}+\overset{\uparrow}{H}$. (*c*) By dissolving an oxide or carbonate in HCl; $ZnO+HCl=ZnCl+HO$. 4. *Iodides* and *bromides*, by direct union, as in iodide of iron, or by double decomposition, as iodide of mercury, $HgCl+KI=Hg\underset{\downarrow}{I}+KCl\rightarrow$. 5. *Sulphates* and *nitrates*, by the action of the acid on the metal, or its oxide or carbonate. (*b*) *Carbonates* are found native or obtained by double decomposition, as in Vallet's mass, FeO,CO_2 (320). The other salts of the oxy-acids are made by direct action of the acid on the oxide of the metal, or its carbonate, or by double decomposition.

245. **Isomorphism.**—Certain bodies of similar chemical constitution have the property of replacing each other in crystalline compounds without altering their crystalline form. In many cases these similar compounds have the same color, and even taste. These bodies are said to be isomorphous (Gr. *isos*, equal, and *morphe*, form).

Strictly speaking, any bodies crystallising in the same system are isomorphous, as the diamond and alum; but the term is restricted to those which have also similar chemical relations. The law of Mitscherlich, that "the same number of atoms similarly combined produce the same crystalline form," although generally correct, cannot be considered as universally true. Examples of isomorphism are found in the alums (301), in which the sesquioxides of aluminum, iron, manganese, and chromium, and potassa, soda, and ammonia replace each other, without change in form, amount of water of crystallisation, &c., and in some cases the compounds are only distinguishable by chemical tests. In *double salts* the two bases are never taken from the same isomorphous family. Isomorphous salts are separated with great difficulty by crystallisation, unless the difference of their solubility is considerable.

The following more important metals are classified in isomorphous groups: (1) Mg, Ca, Mn, Fe, Co, Ni, Zn, Cd, Cu, Cr, Al; (2) Ba, Sr, Pb, K, $\overline{NH_4}$, Na, Ag, Au; (4) Sb, As, Bi.

246. CLASSIFICATION.—The more important metals (in Medical Chemistry) may be thus classified:—

1. **Metals of the Alkalies:** K, Na, Li, $\overline{NH_4}$. Their oxides and carbonates are all soluble; they have a powerful alkaline reaction and are caustic. Their oxides are soluble in alcohol.

2. **Metals of the Alkaline Earths:** Ca, Mg, Ba, Sr. Their oxides have a more feebly alkaline reaction, are less soluble in water; MgO is quite insoluble. Their carbonates and phosphates are insoluble; they form soluble bicarbonates.

3. **Metals of the Earths.** Aluminum is the only important member. Their oxides are insoluble, without alkaline reaction, and combine with both acids and bases.

4. **Metals Proper;** *Heavy Metals; Calcigenous Metals:* Mn, Fe, Cr, Zn, Cd, Sn, Bi, As, Sb, Cu, Pb, Hg, Au, Ag, Pt. Their oxides are precipitated by HS or NH_4S,HS. Hg, Au, Ag, Pt are termed noble metals; their oxides are reduced by heat alone, and they do not decompose water at any temperature.

The following enter into compounds which are *officinal*, U.S.P.: K, Na, Li, NH_4, Ca, Ba, Mg, Al, Fe, Cr, Cu, Cd, Pb, As, Sb, Bi, Hg, Ag.

POTASSIUM, $K=39$.[*]

Syllabus of Compounds.[†]

Oxide (hydrated), KO,HO: (*a*) *Liquor Potassæ;* (*b*) *Potassa.*

Sulphide, *Potassii Sulphuretum,* Liver of Sulphur, $2KS_3+KO,S_2O_2$, variable.

Iodide, KI, *Potassii Iodidum.*

Bromide, KBr, *Potassii Bromidum.*

Cyanide, KCy, *Potassii Cyanidum.*

Ferrocyanide, $K_2Cy_3Fe+3HO$; *Potassii Ferrocyanidum*; Ferricyanide, $K_3Cy_6Fe_2$; Sulphocyanide, $KCyS_2$.

Nitrate, KO,NO_5, *Potassæ Nitras,* Nitre, Saltpetre.

Carbonates: (*a*) *Potassæ Carbonas impura,* Pearlash; (*b*) *Potassæ Carbonas,* KO,CO_2; (*c*) *Potassæ Carbonas pura,* Salt of Tartar; (*d*) *Potassæ Bicarbonas,* $KO,HO,2CO_2$, Sal Aëratus.

Oxalates, KO,C_2O_3+HO; $KO,2C_2O_3+HO,KO,4C_2O_3+7HO$; Salt of Sorrel, Salt of Lemon.

Sulphate, KO,SO_3, *Potassæ Sulphas;* Bisulphate, KO,SO_3+HO,SO_3.

Chlorate, KO,ClO_5, *Potassæ Chloras;* Hypochlorite, $KO,ClO+KCl$, Eau de Javelle.

Acetate, *Potassæ Acetas,* $KO,C_4H_3O_3$, or $KO,\bar{A}$.

Tartrates: (*a*) *Potassæ Bitartras,* $KO,HO,C_8H_4O_{10}$, Cream of Tartar; (*b*) *Potassæ Tartras,* $2KO,C_8H_4O_{10}$, Soluble Tartar; (*c*) *Potassæ et Sodæ Tartras,* $KO,NaO,C_8H_4O_{10}$, Rochelle Salt.

Citrate, $KO,C_{12}H_5O_{12}$: (*a*) *Potassæ Citras;* (*b*) *Liquor*

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[*] Officinal compounds have their names in Latin, also in Italics; the symbols indicate their chemical character.

[†] The *hydrates* of oxides of metals, although ternary compounds, are considered with the anhydrous oxides and other binary compounds for the sake of convenience.

Potassæ Citratis; (c) Mistura Potassæ Citratis, Neutral Mixture. *Potassa cum calce, Alumen, Ferri et Potassæ Tartras, Potassæ Permanganas, Potassæ Bichromas, Liquor Potassæ Arsenitis*, and *Antimonii et Potassæ Tartras* will be considered under the heads of Ca, Al, Fe, Mn, Cr, As, and Sb.

247. *Nat. Sources.*—Exists in many rocks and minerals, as clay, feldspar, mica, etc. These gradually disintegrate and decompose under atmospheric influences; the potassa is taken up from the *soil* thus formed, and assimilated by plants from the ashes of which it is obtained by lixiviation as impure carbonate (potash, pearlash). The leaves and young shoots are richest in potassa.

Prep.—By heating the carbonate to whiteness with C; K distils over.

Prop.—Potassium is a brilliant white metal, silvery lustre, soft at common temperatures; brittle and crystalline at 32°; melts at 144·5°; distils at a low red heat, giving a vapour of a green colour. S. g. 0·865. It has a strong affinity for O, its cut surface instantly tarnishes; it soon oxidises in the air, and must be kept under naphtha or petroleum. It forms with oxygen KO and KO_3, the latter unimportant. POTASSA, KO, is formed by burning K in dry air; it is a white, fusible, volatile body, combining eagerly with HO, with the evolution of heat. It is a powerful base, forming a series of salts most of which are colourless and soluble. The best TEST is bichloride of platinum, $PtCl_2$, which forms a yellow, sparingly soluble double chloride, $KCl + PtCl_2$. With *Sulphur* it forms five compounds, KS, KS_3, and KS_5 being the most important. The other compounds of K and KO will be considered in detail hereafter.

248. (1) **Hydrate**, KO,HO; *Liquor Potassæ.*—Is made as follows: Take of *Potassa Bicarb.* ℥xv, *Calcis* ℥ix,

Aquæ Destillatæ q. s. Dissolve the bicarbonate in Oiv of the water, and boil until effervescence ceases; add enough to make up the loss by evaporation; then mix the lime with Oiv water, heat to the boiling-point in a metallic vessel, add to the potassa solution, and boil for 10 minutes; strain through a muslin strainer, and add to the residue on the strainer enough distilled water to make Ovij. Keep in well-stoppered green glass bottles. It may also be made by dissolving *Potassa*, U. S. P., ℥i, in Oj of distilled water, pouring off the solution from any sediment that may deposit.

The bicarbonate is selected on account of its purity; it loses CO_2 during the boiling, becoming sesqui-carbonate. The lime forms an insoluble compound with CO_2, and therefore acts as the stronger base (170). With KO,CO_2, the reaction would be, $KO,CO_2+CaO,HO=CaO,C_{\downarrow}O_2+KO,HO_{\rightarrow}$. Green glass bottles are less liable to be attacked by alkaline solutions than those of ordinary glass.

Prop. and Med. Effects.—A corrosive, colourless liquid, s. g. 1·065, containing $5\frac{8}{10}$ per cent. of KO,HO. Has a powerful affinity for CO_2. In *large doses*, a corrosive poison; antidotes: weak acids and oily matters. In *medicinal doses*, gtt xx t. d. is given as an antacid and alterative. Used in gout, rheumatism, chronic skin diseases, obesity, etc. Should be given diluted in milk. Is *incompatible* with all acids, acid salts, and those of the metals generally, except sodium.

Potassa, Caustic potash, Potassa fusa, KO,HO, is made by evaporating Liquor potassæ in an iron vessel until boiling ceases and the potassa melts; it is then poured into moulds. It is a white, deliquescent solid, producing a soapy feel when rubbed between the fingers, from the destruction of the cuticle. The commercial article is impure and of a grayish colour; it may be purified by alcohol, which dissolves the KO,HO, and leaves most of the impurities. It is used externally as an escharotic; from its deliquescent character is apt to spread. It may be neutralised by weak vinegar.

249. (2) **Sulphide,** *Potassii sulphuretum,* Hepar sulphuris, Liver of sulphur. *Prep.*—By heating ℥j *Sulphur Sublimat.* mixed with ℥ij *Potassæ carb.* until effervescence ceases and the mass melts; it is then poured upon a slab, and when cool broken into pieces; $3(KO,CO_2)+S_8=2KS_3+KO,S_2O_2+3CO_2$. Is a mixture of tersulphide of K with hyposulphite of KO; on exposure to the air, it gradually absorbs O, and becomes converted into sulphate.

Prop.—A liver-coloured, uncrystalline mass, smelling of HS, which is freely evolved by the addition of dilute acids. It is freely soluble in water. *Med. Effects.*—In overdose, a poison irritating the stomach, depressing the nervous system and the action of the heart. *Antidote*: Sulphate of zinc, ZnO,SO_3. Is rarely used internally; externally is applied as a lotion, gr. xv to xxx to ℥j *Aquæ* in chronic skin diseases. Its odour may be disguised by oil of Anise (Ruschenberger). Is *incompatible* with acids, acidulous salts, and those of the metals generally.

250. **Bromide,** KBr; *Potassii Bromidum.*

Prep.—Is generally made on the large scale; ℥ij of bromine are added to ℥j of iron filings in Oiss of distilled water. They combine, by the aid of a gentle heat, to form a greenish solution of FeBr; to this is added ℥ij, gr. lx, of pure carbonate of potassa, dissolved in Oiss of distilled water, until no further precipitate is produced. The precipitate is washed and the filtrate crystallised, $FeBr+KO,CO_2=\underset{\downarrow}{FeO,CO_2}+KBr.\rightarrow$

Prop.—In cubic crystals resembling KI; is sparingly soluble in alcohol; should not lose weight on being heated. Its taste resembles that of NaCl.

Med. Effects.—Has a marked sedative action on the nervous system; causes anæsthesia of the fauces; is administered before operations or examinations of the throat; used in epilepsy, sleeplessness, and other nervous disorders, in engorgement of the uterus and prostate, spermatorrhœa, etc. Dose, gr. v to xxx, t. d. *Incompatibles,* those of the iodide.

251. **Iodide,** KI; *Potassii Iodidum.*

Prep.—Is generally prepared on the large scale. Iodine ℥xvi is boiled with potassa ℥vi in Oiij of distilled water. The solution is evaporated to dryness, mixed with powdered charcoal ℥ij and heated for 15 minutes to redness in an iron crucible. The mass is lixiviated and the salt crystallised out. (1) $6KO+I_6=KO,IO_5+5KI$; (2) $KO,IO_5+C_6=KI+6CO$.

Prop.—Anhydrous, cubic crystals (1st system), opaque white, or transparent; of a saline, cooling, disagreeable taste; soluble in two-thirds its weight of cold water and 6 or 8 parts of cold alcohol.

Impurities and Adulterations.—Bromide of potassium, sometimes sold for the iodide, does not precipitate with corrosive sublimate. The most common impurities are: 1. *Chlorides,* which, with nitrate of silver, throw down a white precipitate, $AgCl$, freely soluble in ammonia. KI throws down iodide of silver, AgI, which is scarcely soluble in ammonia. 2. *Bromides,* which may be detected by removing all the I from the liquid by sulphate of copper and SO_2, and testing for bromine. Iodate and carbonate of potassa may be detected by their insolubility in alcohol. If the iodide should be very deliquescent, KO,CO_2 may be suspected.

Med. Effects.—Those of iodine generally. Used in slow poisoning by mercury and lead; which it is supposed to convert in the tissues into iodides, which it afterwards dissolves. May thus render mercury active, and produce salivation. Dose, gr. v to xxx; has been given in ℥ss doses.

Incompatibles.—Mineral acids, salts of copper, lead, silver, iron, manganese; all the preparations of mercury, except the red iodide—tartaric acid.

UNGUENTUM POTASSII IODIDI, is made by rubbing up gr. lx *Potass. Iodid.*, dissolved in fʒj *Aquæ*, with ℥j *Adipis.*

252. **Cyanide**—*Potassii Cyanidum*—KCy. Is *prepared* by melting together a mixture of ℥viii dried ferrocyanide of potassium, K_2Cfy, and ℥iij of pure carbonate of potassa, KO,CO_2; iron is precipitated, and the fused mass is poured off, and, when cool, broken into pieces, which must be kept in well-stopped bottles. The product is a mixture of KCy with cyanate of potassa, KO,CyO, and other impurities. It contains on the average not more than 50 p. c. of KCy. Pure KCy in crystals may be obtained by passing a current of HCy into a solution of KO,HO in alcohol.

Prop.—Is a white, amorphous, deliquescent mass, of an acrid taste, a smell of HCy, and irritating to the skin; it is very soluble in water, and sparingly so in alcohol. It slowly evolves HCy on exposure to the air, and rapidly by the action of dilute acids. Is much used as a solvent of silver in photography and electro-plating. It will remove nitrate of silver stains from the hands or clothing.

Med. Effects.—Those of HCy; is uncertain, and rarely administered internally. Cases of poisoning by it are not unfrequent. The stomach should be evacuated, and the antidotes for HCy administered.

253. **Ferrocyanide**, $K_2Cfy+3HO$; *Potassii Ferrocyanidum;* yellow prussiate of potash.

Prep.—On the large scale by heating refuse animal matter containing N, with pearlash and scrap iron in an iron vessel. May be made by digesting iron filings with KCy.

Prop.—Large, transparent, lemon-yellow crystals, square octohedra (2d system); inodourous, of a sweetish saline taste; soluble in about 4 parts of cold and one of boiling water; insoluble in alcohol. Loses its water of crystallisation at 126°, and becomes white. Is valuable as a *test;* used as a source of HCy and KCy; also in the manufacture of Prussian blue, Fe_4Cfy_3, and in dyeing. Is not poisonous, and is rarely used in medicine.

Ferricyanide of potassium, K_3Cfdy, red prussiate of potash (237), occurs in ruby red, inflammable crystals (2d system), soluble in 4 parts water. Is used as a test and in dyeing, but not in medicine. *Sulphocyanide of potassium*, KC_2NS_2, made by digesting the cyanide with sulphur, is used as a test. It exists in the saliva of man (236).

254. **Nitrate**, KO,NO_5, *Potassæ Nitras*, Nitre, Saltpetre.

Prep.—May be made by adding HO,NO_5 to KO,HO or KO,CO_2. Exists in many caves in the southwest portion of the United States, also in India, Egypt, Peru, and many parts of Europe. Is formed artificially on the large scale in nitre beds.

N and O combine directly under the influence of the electric spark; indirectly, when in the nascent state (143), especially when in the presence of a powerful base, or when absorbed by porous bodies (121). Thus charcoal exposed to the effluviæ of sewers contains nitrates from the combustion of ammonia. The researches of Kuhlmann on the influence of platinum sponge have shown that any gaseous compound of N, in excess of O, will produce nitric acid.

Prop.—Exists in colourless, anhydrous, hexagonal prisms (6th system); of a sharp, cooling taste; soluble in 7 parts cold and its weight of boiling water; insoluble in alcohol. When fused below a red heat and cast into moulds, forms *sal prunelle;* at a higher temperature yields a part or all of its O. Is used in the manufacture of nitric acid and gunpowder, also in pyrotechny.

Med. Effects.—In large doses, an irritant poison; no direct antidote is known. In small doses, gr. i to x, is supposed to be refrigerant, diuretic, and diaphoretic. Has been employed in fevers, croup, asthma, rheumatism, etc. Is not now much administered. Paper, soaked in a strong solution, dried and lighted, burns slowly giving off fumes, which when inhaled afford much relief in some cases of spasmodic asthma.

255. **Carbonates.**

Potassæ Carbonas impura, Pearlash, is obtained by lixiviating the ashes of plants; it contains many impurities. When mixed with its weight of cold water, it dissolves, leaving *most* of these behind, and on evaporation gives:—

Potassæ Carbonas, KO,CO_2. A white granular deliquescent body of nauseous taste and alkaline reaction. Is not quite pure.

Potassæ Carbonas pura, Salt of tartar. Is made by heating and then igniting the bicarbonate. Was formerly prepared by heating *cream of tartar,* whence its popular name. In its properties it resembles the last-named salt.

Potassæ Bicarbonas, KO,CO_2+HO,CO_2, or $KO,HO,2CO_2$.

Prep.—Is made by passing a current of CO_2 through a solution of ℥xlviii of *Potass. Carb.* dissolved in *Aq. Destillat.* Ox until no more is absorbed. The solution is filtered and evaporated at a temperature not exceeding 160°.

Prop.—Transparent crystals (3d system), soluble in 4 parts of cold water; when the solution is boiled, a portion of CO_2 is given off. It is free from impurities which are left behind during filtration and crystallisation. It may contain a portion of unsaturated carbonate, in which case it will give a brick-red precipitate with a solution of corrosive sublimate. *Sal aëratus* is the older name for the bicarbonate, but is now usually applied commercially to a powder containing a portion of unsaturated carbonate. The bicarbonate is less disagreeable, irritating, and alkaline than the carbonates, and being pure is used in making many of the other preparations of KO. At a red heat it loses HO and CO_2 and becomes KO,CO_2.

Med. Effects.—The carbonates of potassa, dose gr. x to xxx, are antacid, used in gout, rheumatism, lithiasis, etc. They are incompatible with all acids, acidulous salts, and those of the metals generally.

256. **Oxalates.**—Oxalic acid forms with KO: (1) *Neutral* oxalate of potassa, KO,C_2O_3+HO; (2) Binoxalate, $KO,2C_2O_3+HO$, found in certain plants, as *Rumex, oxalis acetosella,* and garden rhubarb; (3) Quadroxalate, $KO,4C_2O_3+7HO$. The two latter are sold as *Salts of sorrel,* or *Salt of lemons,* and are used for removing iron mould and ink stains. They possess the poisonous properties of OXALIC ACID (210).

257. **Sulphate,** KO,SO_3, *Potassæ sulphas.*—May be made by the action of HO,SO_3 on those salts of KO which it decomposes. Is a residue from making nitric acid on the large scale. Is in *hard* anhydrous crystals (6th system), soluble in 10 parts water. Is purgative, but rarely used in medicine; from their hardness the crystals are employed in making *Dover's powder,* serving to comminute and intermingle the Ipecac. and Opium; from the same property when undissolved they may act as an irritant poison. *Bisulphate of potassa,* KO,SO_3+HO,SO_3, or $KO,HO,2SO_3$, is a residue after making HO,NO_5 on the small scale, has an acid reaction, is soluble in two parts water; is used to

adulterate cream of tartar. By dissolving ℥j each of this salt and *Potass. carb. pura* separately in water, and then mixing them, a cheap, effervescent, purgative draught is obtained.

258. **Chlorate,** KO,ClO_5; *Potassa Chloras.*

Prep.—(1) By passing a current of Cl through a weak solution of KO,HO; $6KO+Cl_6=KO,ClO_5+5KCl$. (2) By the reaction of KCl and $3(CaO,ClO)=KO,ClO_5+3CaCl$. The chlorate is separated by crystallisation.

Prop.—In flat, pearly, tabular anhydrous crystals (5th system), having but little taste, soluble in 20 parts cold and 2 boiling water. Gives up all its O at a red heat, and deflagrates even more violently than the nitrate. Strong acids liberate ClO_4, which is yellowish and explosive. Rubbed with powdered sulphur, explosion ensues; this should be borne in mind in dispensing it.

Med. Effects.—Passes unchanged into the urine; has been successfully employed internally and locally in various throat affections, cancrum oris, ptyalism, aphthæ, scarlatina, diphtheria, etc. Dose, gr. x to xxx. Is only decomposed by strong acids. Should give no precipitate with AgO,NO_5 (absence of *chloride*).

259. **Acetate,** $KO,C_4H_3O_3$, *Potassæ Acetas,* Sal diureticus.

Prep.—By saturating acetic acid with bicarbonate of potassa, and evaporating gently to dryness. In all cases of union of an acid and alkaline base, the point of saturation may be determined approximately by the taste and accurately by litmus-paper.

Prop.—A deliquescent white foliated mass, soluble in one-half its weight of water and 2 parts of alcohol. It should not affect test-paper; if it has been heated too highly, will be alkaline from the loss of the volatile acetic acid. It should be entirely soluble in water and alcohol; this test shows the absence of ordinary impurities.

Med. Effects.—Is a powerful diuretic gr. x to xxx, and cathartic ʒj to ʒiij. Used in dropsy, skin diseases, and rheumatism. It renders the urine alkaline. As it is easily decomposed, should be given alone in solution in water. May be made extemporaneously by saturating weak vinegar with sal aëratus or salt of tartar; ʒj to ʒij of the latter being used for a dose as a cathartic.

TARTRATES.

260. **Potassæ Bitartras,** $KO,HO,C_8H_4O_{10}$, or $KO,HO,\bar{T}$.* Cream of tartar, acid tartrate of potassa.

Prep.—Occurs impure as *Argols,* a reddish or dirty white deposit in wine-casks. This is purified by solution in boiling water and recrystallisation.

Prop.—Hard gritty crystals (3d system), soluble in 184 parts cold and 18 of boiling water, of a slight agreeable acid taste. Is entirely decomposed by heat, leaving charcoal and pure KO,CO_2. Its slight solubility should be borne in mind in prescribing. The addition of $\frac{1}{3}$ part by weight of borax will render cream of tartar soluble in 16 parts of boiling water, and it will not deposit on cooling. When sold in powder, is very apt to be adulterated; should be bought in crystals.

Chem. and Med. Effects.—Tartaric acid is *bibasic;* in cream of tartar but one equivalent of the basic water is replaced by a base, it has therefore acid properties. By replacing the second eq. of water with KO, we get *neutral* tartrate, Soluble tartar; with NaO, *Rochelle salt,* with Fe_2O_3, *Ferri et Potassæ Tartras,* and with SbO_3 *tartar emetic.* Cream of tartar is cathartic, diuretic, and refrigerant. Used in dropsy, ʒj to ʒiij t. d., as a hydragogue and diuretic. Its solution, made with boiling water and allowed to cool, forms a laxative and cooling drink. Is *incompatible* with alkalies, alkaline earths, and their carbonates; sulphides, acetate of lead.

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* Compounds of the acids generally regarded as organic with the inorganic bases will be considered with the latter, as more convenient. The organic acids are conventionally represented by their initial letter with a dash over it.

Potassæ Tartras, $2KO,C_8H_4O_{10}$; Soluble tartar.

Prep.—By boiling ℥xvi *Potass. carb.* with ℥xxvi powdered *Potass. Bitart.* in Oj *Aquæ bullient.*, the cream of tartar being gradually added to saturation. The solution is evaporated and crystallised, $KO,HO,\overline{T} + KO,CO_2 = 2KO,\overline{T}_{\rightarrow} + CO_2\uparrow$.

Prop.—White, neutral, slightly deliquescent crystals (4th system), soluble in one part cold and one-half of boiling water; insoluble in alcohol. Is decomposed by heat like the bitartrate. Its taste is saline and bitter. Is purgative; *dose,* ʒj to ℥j; but little used; is *incompatible* with the mineral acids and the salts of lime, baryta, and lead.

Potassæ et Sodæ Tartras, $KO,NaO,C_8H_4O_{10}$, Rochelle or Seignette salt. Made as the last preparation, using ℥xii *Sodæ Carbonatis* instead of *Potass. Carb.*, $KO,HO,\overline{T}+NaO,CO_2=KO,NaO,\overline{T}_{\rightarrow}+CO_2\uparrow$.

Prop.—Large, transparent, prismatic, slightly effervescent crystals (3d system); soluble in 2½ parts of cold water; taste saline and slightly bitter; is among the least offensive of the salines. Should be neutral to test-paper, and give no precipitate with BaCl (absence of sulphates), or AgO,NO_5 (absence of chlorides).

Med. Effects.—Laxative ʒj, purgative ℥ss to ℥j; may be administered with tartar emetic; renders the urine alkaline when absorbed. *Incompatibles*, those of the tartrate. Is largely employed in the form of:—

Pulveres Effervescentes Aperientes—Seidlitz powders. (1) ℞. *Sodæ Bicarb. pulv.* ℥j, *Potassæ et Sodæ Tartrat.* ℥iij, ♏ *et ft. chart.* No. xii; wrap in blue paper. (2) ℞.

Acid. Tartaric. pulv. gr. ccccxx, *ft. chart.* No. xii; wrap in white paper. The blue and white papers are dissolved separately in water, mixed, and the draught swallowed in a state of effervescence. Much less water is required for the white than for the blue packet. For a cheap substitute, see *bisulphate of potassa.*

Remarks.—The blue paper contains ʒij Rochelle salt with gr. xl of *sodæ bicarb.*; the white paper, gr. xxxv *acid. tartaric.* When mixed, the free acid unites with the soda of the bicarbonate, liberating CO_2, and forming tartrate of soda. They should be kept dry.

261. **Citrate,** $3KO,C_{12}H_5O_{10}$; *Potassæ Citras.*

Prep.—By dissolving *acid. citric.* ℥x in Oij *aquæ destillat.*, and adding gradually ℥xiv *potassæ bicarb.* When effervescence has ceased, filter and evaporate to dryness with constant stirring.

Prop. and Med. Effects.—A granular white powder, of a saline, slightly bitter taste, deliquescent and very soluble in water; insoluble in alcohol. By heat yields C and KO, CO_2. As above prepared, is quite pure. Is esteemed refrigerant and diaphoretic; much used in fevers.

Liquor Potassæ Citratis. ℞. *Acid. Citric.* ℥ss, *Potassæ Bicarb.* gr. cccxxx, *Aquæ* Oss, *solve et cola.** A convenient extemporaneous form. *Dose,* a tablespoonful.

Mistura Potassæ Citratis, neutral mixture. ℞. *Succ. Limonis recentis* Oss; *Potass. Bicarb.* q. s. *ad saturitat.*; *cola.* This is a more agreeable preparation than the last, having the flavour of the fresh lemon-juice, and retaining some of the liberated carbonic acid. In practice the juice of one lemon is allowed to a f℥vj mixture, and is not quite neutralised. *Dose,* a tablespoonful.

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* *Cola,* strain; in this case through *muslin.*

SODIUM, $Na=23$.

Syllabus of Preparations.

Hydrate, NaO,HO; *Liquor Sodæ.*

Chloride, $NaCl$; *Sodii Chloridum.*

Nitrate, NaO,NO_5; Cubic nitre.

Carbonates: (*a*) *Sodæ Carbonas*, Sal Soda, NaO,CO_2+10HO; (*b*) *Sodæ Carbonas Exsiccata*, NaO,CO_2; (*c*) *Sodæ Bicarbonas*, NaO,CO_2+HO,CO_2, or $NaO,HO,2CO_2$, *Pulveres Effervescentes.*

Sulphate, NaO,SO_3+10HO; *Sodæ Sulphas*, Glauber's salt.

Sulphite, NaO,SO_2+3HO, *Sodæ Sulphis*; Bisulphite, $NaO,HO,2SO_2$; Hyposulphite, NaO,S_2O_2+5HO.

Phosphates; *Sodæ Phosphas*, $2NaO,HO,PO_5+24HO$; Sal perlatum.

Hypochlorite, $NaO,ClO+NaCl$; *Liquor Sodæ Chlorinatæ*, Labarraque's solution.

Borate, $NaO,2BO_3$; *Sodæ Boras*, Borax.

Silicates.

Acetate; *Sodæ Acetas*, $NaO,C_4H_3O_3+6HO$.

Valerianate, $NaO,C_{10}H_9O_3$; *Sodæ Valerianas.*

262. *Nat. Sources.*—Common salt, certain plants and minerals; see Carbonate of Soda. Abundant in animal forms.

Prep.—From carbonate of soda by reduction with C.

Prop.—Resembles K, but is less easily oxidised; in dry air forms a crust which preserves the metal within; does not take fire on water unless the latter be warm or the metal prevented from moving about. Is soft, silvery, s. g. 0.97; melts at 207°, and gives a colourless vapour at a white heat. It burns with a characteristic yellow flame.

Chem. Rel.—With O forms soda, NaO, and NaO_2; its compounds correspond with those of K in most respects, are generally more soluble. Its salts are colourless and all soluble. Its presence is determined by *exclusion* (174), by the yellow colour communicated to flame, by its salts, and by its characteristic yellow line in the spectroscope.

263. **Hydrate**, NaO,HO.

Liquor Sodæ, solution of caustic soda, is made in the same manner as *Liq. Potassæ;* the proportions of (crystallised) carbonate of soda and of lime are ℥xxvi of the former to ℥viii of the latter; s. g. of the solution 1·071, and it contains 5·7 p. c. of KO,HO. The solid hydrate is largely sold as *concentrated lye;* is used as a powerful detergent and in soap-making.

264. **Chloride**, $NaCl$, *Sodii Chloridum*, Chloride of Sodium, Common Salt, $NaCl$.

Prep.—Is obtained from sea-water, salt springs, or salt mines (rock-salt) in which it exists native. Sea-water (188) or that of salt springs is evaporated, until the greater part of the $NaCl$ crystallises out; the mother liquor, holding in solution the more soluble salts, as the Chloride of Magnesium, $MgCl$, the Sulphate of Soda, NaO,SO_3, etc., is drawn off, constituting *bittern.*

Prop. and Med. Effects.—Anhydrous cubes (first system); of a well-known, agreeable taste; when pure, does not alter in the air; soluble in about 3 parts water; the solubility is not increased by heat. In small doses, is tonic and anthelmintic; in large ones, emetic and purgative; used in hæmoptysis. Is the antidote to *Nitrate of Silver.*

Impurities.—Insoluble matters, Chlorides of Calcium and Magnesium, Sulphates of Soda and Lime.

Incompat.—Strong Sulphuric Acid, NO,SO_3, Nitrate of Silver, AgO,NO_5, Nitrate of Mercury, HgO,NO_5, soluble lead salts.

265. **Carbonates.**

Sodæ Carbonas, NaO,CO_2+10HO, Sal Soda, Washing Soda.

Sources.—(1) Native carbonate *natron* is found in Hungary, Egypt, South America, and California. It is irregular in composition. (2) *Barilla*, the ashes of the salsola soda and other plants growing near the sea. (3) *Kelp*, the ashes of sea-weed. (4) Artificially from common salt, $NaCl$, or cryolite, $3NaF+Al_2F_3$.

Prep.—(1) From common salt (Le Blanc's process). The salt is first converted into sulphate (salt-cake), $NaCl+HO,SO_3=NaO,SO_3+HCl$. This is mixed with powdered limestone and coal made into balls and heated in a reverberatory furnace. The black mass resulting is lixiviated with hot water, the solution evaporated to dryness and again calcined with sawdust. The mass is again lixiviated and crystallised.

The reaction is complex and variable. It is essentially $NaO,SO_3+C_4+CaO,CO_2=NaO,CO_2+CaS+4CO$. An excess of lime is used, and there is formed in addition some oxy-sulphide of calcium, $CaO,3CaS$.

(2) From cryolite, $3NaF+Al_2F_3$. This mineral is found abundantly in Greenland. It is mixed thoroughly with powdered chalk and calcined, $\overline{3NaF+Al_2F_3}+6(CaO,CO_2)=6CaF+3NaO+Al_2O_3$. The soda remaining in solution is converted into carbonate by a stream of CO_2, the liquid drawn off and crystallised.

Prop.—In colourless, efflorescent, oblique rhombic prisms (4th system); of an alkaline reaction and harsh, disagreeable taste; soluble in half its weight of cold water and $\frac{1}{833}$d at 970; its solubility decreases above this point; is insoluble in alcohol. When heated, the crystals melt in their water of crystallisation; this is driven off, and finally the salt melts. The crystals contain about 60 p. c. of water.

Med. Effects.—In large doses, an irritant poison; antidotes: weak acids and oily matters. In medicinal doses, gr. x to xx, those of *Potass. carb.* Is used externally as a detergent in skin diseases. Is *incompatible* with acids, acidulous salts, those of the metals generally, lime water, CaO,HO, and muriate of ammonia, NH_4Cl.

Sodæ Carbonas Exsiccata is made by heating *Sodæ carb.*, stirring constantly until dried. It is used for making into pills and as a blowpipe reagent. Dose, gr. v to xv.

Sodæ Bicarbonas, $NaO,HO,2CO_2$, Supercarbonate of soda, Soda sal aëratus.

Prep.—By passing CO_2 over *Sodæ Carbonas* conveniently placed on perforated wooden shelves. The water of crystallisation runs off, and the crystals become opaque and powdery.

Prop. and Med. Effects.—A white powder of an alkaline taste and reaction; soluble in 13 parts cold water; is converted by boiling water into sesquicarbonate, $2NaO,3CO_2$. It is used in the same cases as the Potass. Bicarb. in the preparation of Seidlitz powder (260), and of the *Pulveres effervescentes*, soda powders. These form a convenient, extemporaneous substitute for soda water, *Aqua acidi carbonici* (208). The blue papers contain ʒvj of *Sodæ Bicarb.* in fine powder, and the white, ʒv of *Acid. Tartaric.*, each divided into 12 packets. These are dissolved separately in water, mixed and swallowed in a state of effervescence. One or two constitute a dose. Tartrate of soda is formed.

266. **Sulphate,** NaO,SO_3+10HO; *Sodæ Sulphas,* Glauber's salt, Sal mirabile, Salt cake.

Prep.—By the action of sulphuric acid upon common salt (265). Is a residue in the manufacture of HCl, and other chemical processes.

Prep.—Long colourless, efflorescent, hexagonal prisms, (6th system), of a saline, bitter taste. Soluble in 5 parts cold water and 2 at 91°, which is its temperature of maximum solubility. The crystals contain 75 p. c. water in which they readily melt by heat and lose entirely in dry air at common temperatures. Is purgative, but is rarely used in medicine.

267. **Sulphite,** *Sodæ Sulphis,* NaO,SO_2+3HO.

Prep.—By passing a current of SO_2 through a solution of NaO,CO_2 until all the CO_2 is given off, evaporating the solution and crystallising.

Prop.—White prismatic crystals (3d system) having a slightly alkaline reaction; soluble in 4 parts of cold and their weight of boiling water. The solution has a characteristic odour. The salt on exposure to the air gradually absorbs O, becoming sulphate; on the addition of acids, SO_2 is evolved. By passing SO_2 through the solution of NaO,CO_2 *to saturation,* a bisulphite, $NaO,HO,2SO_2$, is formed, which has an acid reaction and the smell and taste of SO_2, which it evolves on exposure to the air.

Med. Effects.—Those generally of SO_2. Is used externally in skin diseases, and internally in zymotic affections. Dose, ʒj t. d. The *hyposulphite,* NaO,S_2O_2+5HO, is officinal in the British Pharmacopœia. It is in large, colourless, prismatic crystals (3d system), soluble in rather more than half its weight of water at 60°, and insoluble in alcohol. It is used in the arts as a solvent of silver compounds. It is given in the same cases as the sulphite. Dose, gr x to xx t. d.

268. **Phosphates.**

Rem.—The peculiarities of PO_5 in combining with one, two, or three eq. of water or a base, and the numerous salts thus formed, have already been discussed (220). Of the phosphates of soda there named but one is officinal:—

Sodæ Phosphas, $2NaO,HO,PO_5+24HO$, Sal perlatum, tasteless purging salt, rhombic phosphate of soda.

Prep.—By saturating the excess of PO_5 in superphosphate of lime (obtained by treating calcined bones with HO,SO_3) with NaO,CO_2; $2NaO,HO,PO_5$ is formed and crystallised out.

Prep. and Med. Effects.—Large, colourless, efflorescent, oblique rhombic (4th system) crystals; they have a taste resembling NaCl, are soluble in 4 parts cold and 2 of boiling water; insoluble in alcohol. When gently heated, the salt loses its water of crystallisation, and at a red heat its basic water, becoming pyrophosphate, $2NaO,PO_5$. The tribasic salt gives a *yellow*, the *bibasic* a white, and the *monobasic*, metaphosphate NaO,PO_5, also a white precipitate with AgO,NO_5. Is purgative. Dose, ℥j to ℥jj. From the similarity of its taste to common salt may be given in broth or soup.

269. **Hypochlorite**, $NaO,ClO+NaCl$; *Liquor Sodæ Chlorinatæ;* Labarraque's solution.

Prep.—Dissolve ℥xxiv *Sodæ Carb.* in Oiij *Aquæ;* to this add ℥xii *Calcis Chlorinatæ* (291) mixed smoothly with water; then add enough water to make Oxii. Shake well and set aside for 24 hours; decant the clear liquid and drain the precipitate on a muslin strainer, adding water if necessary, until the whole amount of liquid is Oxiss. Keep in a well-stoppered bottle excluded from the light. $CaO,ClO+CaCl+2(NaO,CO_2)=\overline{NaO,ClO+NaCl}+2(CaO,\underset{\downarrow}{C}O_2)$. In the proportions of the U. S. P. given above, there is an excess of NaO,CO_2, which renders the solution more permanent.

Prep. and Med. Effects.—A transparent solution having slightly the colour and smell of Cl, which it evolves with a little CO_2, on the addition of HCl; it bleaches and deodourises. Is one of the most elegant, permanent, and manageable of the chlorine solutions. Used in scarlatina and other anginose affections. Dose, gtt x to xxx; externally, is largely used in gargles and lotions to ulcerated and offensive parts, also in chronic skin diseases and as a general deodouriser.

270. **Borate,** $NaO,2BO_3+10HO$, *Sodæ Boras*, Borax.

Prep.—Occurs native and is made by the addition of native boracic acid, BO_3, to soda.

Prop.—A white, crystalline salt (3d system), soluble in 12 parts cold and 2 of boiling water; taste, sweetish alkaline; reaction, alkaline; exposed to the air, effloresces; contains ordinarily 10 eqs. water of crystallisation, in which it fuses at a moderate heat; at a higher heat, loses its water of crystallisation and fuses, forming, when cool, *glass of Borax*; glass of borax dissolves most metallic oxides, which colour it; hence its use in blowpipe analysis. Is a biborate of soda.

Med. Effects.—Refrigerant and diuretic; has the property of rendering cream of tartar freely soluble in water. Dose, gr x to xxx. Generally used, rubbed up with sugar and honey, as a mild astringent in aphthous sore mouth of children. (*Mel Sodœ boratis, U. S. P.*)

The *silicates of soda* will be considered under GLASS.

271. **Acetate,** $NaO,C_4H_3O_3+6HO$; *Sodæ Acetas. Prep.*—By saturating *Sodœ bicarb.* with *Acid. acetic. Prop.*—Long, white, efflorescent, striated prisms (4th system), soluble in 3 parts of cold water and 40 of alcohol. When heated, the salt melts in its water of crystallisation and is finally decomposed into C and NaO,CO_2. It resembles acetate of potassa in medical properties; dose, gr xx to gr cxx.

272. **Valerianate,** $NaO,C_{10}H_9O_3$; *Sodæ Valerianas.*—*Prep.*—Is made by saturating Valerianic acid, $HO,C_{10}H_9O_3$, obtained by the action of bichromate of potassa, $KO,2CrO_3$, on Fusel oil, $C_{10}H_{11}O,HO$(414). Is not admin-

istered in medicine, but is used for the preparation of the valerianates of zinc, morphia, and quinia.

273. **Lithium**, Li=7.—Is a rare metal found in combination in Spodumene, Petalite, and in certain mineral waters. Is obtained by the electrolysis of its fused chloride. Is the lightest solid body known, s. g. 0·594. Its carbonate, officinal as *Lithiæ Carbonas*, is a white powder soluble in 100 parts of cold water and communicating a red tinge to flame. It is antacid, used in lithic diathesis, gout, etc.; may be given in solution in *Aquæ Acid. Carbonic.* It is distinguished from *strontia* by the solubility of its salts in HO,SO_3.

AMMONIUM, NH_4=18. (Hypothetical.)

SYLLABUS.

OXIDE, NH_4O, *Ammonia; (a) Aqua Ammoniæ fortior; (b) Aqua Ammoniæ; (c) Linimentum Ammoniæ; (d) Spiritus Ammoniæ; (e) Spiritus Ammoniæ aromaticus* (contains carbonate also).

CHLORIDE, NH_4Cl, *Ammoniæ Murias*, Sal Ammoniac.

CARBONATES, *Ammoniæ Carbonas*, $2NH_4O,3CO_2$; Bicarbonate.

NITRATE, NH_4O,NO_5.

SULPHATE, NH_4O,SO_3, *Ammoniæ Sulphas.*

SULPHUR SALT, NH_4S,HS, Sulphydrate of Ammonia.

ACETATE, $NH_4O,C_4H_3O_3$, *Liquor Ammoniæ Acetatis*, Spirit of Mindererus.

VALERIANATE, $NH_4O,C_{10}H_9O_3$, *Ammoniæ Valerianas.*

274. *Remarks.*—N and H combine in the nascent state, especially when the latter is in excess, to form a gaseous body, *Ammonia*, which when dry yields, on analysis, NH_3. This body combines with hydrated acids to form well-marked saline compounds, which however always contain

an equivalent of water. Thus $NH_3+HO,SO_3=NH_3HO,SO_3$. It is assumed from analogy with other bases that this water is essential, and that ammonia *as a base* has the formula $NH_4O=NH_3,HO$; the sulphate would then be, NH_4O,SO_3, analogous to that of KO or NaO. NH_4 has never been isolated. Chemists also suppose the existence of NH *imidogen*, and NH_2 *amidogen*, hypothetical bodies. The fact of the formation of an amalgam in which NH_4 may be supposed to exist lends support to the above view which is adopted as convenient and probably correct.

Ammonium Amalgam.—(1) When mercury is connected with the negative (zinc) pole of a voltaic battery in a solution of ammonia, it swells, becomes pasty, and assumes the characters of an amalgam. O is given off at the + pole, but there is no corresponding evolution of H at the — pole until the current is interrupted; the amalgam then speedily decomposes, yielding mercury, ammonia, and H (2) When an amalgam of sodium and mercury is thrown into a saturated solution of *sal ammoniac*, NH_4Cl, it increases to several hundred times its original bulk and has the characters and undergoes the changes mentioned above The following reaction is supposed to take place: $NaHg+NH_4Cl=NH_4Hg+NaCl$. This hypothetical metal NH_4, ammonium, resembles in its chemical relations KO and NaO. Its salts are all volatile or decomposed by heat; they may be recognised by the evolution of gaseous ammonia, NH_4O, upon the addition of lime or caustic alkali.

275. **Ammonia, NH_4O.**

Sources.—Is formed during the destructive distillation of organic matters containing or in the presence of N; also during putrefaction, the decomposition of the cyanides, the rusting of iron, and the action of dilute HO,NO_5 upon certain metals. Is prepared upon the large scale from the liquor obtained from the hydraulic main, washers, and condensers of gas-works. This is neutralised with HO,SO_3, which fixes the ammonia, and on evaporation NH_4O,SO_3 is crystallised out. From this the other compounds may be obtained. By using HCl, NH_4Cl is obtained directly.

Prep.—On the large scale by heating the crude sulphate with milk of lime, $NH_4O,SO_3 + CaO,HO = NH_4O,HO + CaO,SO_3$. The gas is absorbed by water kept cold. It may be prepared on the small scale by heating its solution *Aqua Ammoniæ.* It must be collected over mercury or by displacement, in the latter case the delivery tube passing to the top of the receiver.

Prop.—A colourless, irrespirable gas, s.g. 597; liquid at —40°, or by a pressure of 6 atmospheres at 40°; solid at —103°. It will burn in air if a light be held in a jet of the gas, and in Cl. Has a powerful alkaline reaction, hence termed volalile alkali. Water at 32° absorbs 1000 vols. (Bunsen); at 50°, 670 vols., increasing in bulk about two-thirds. It is also soluble in alcohol. The strongest solution in water has a s.g. 0·875, and contains 32·5 p.c. of liquid ammonia. This boils at 130°, giving up the gas, and gelatinises at —40°.

276. **Officinal Forms.**

(*a*) *Aqua Ammoniæ Fortior,* s.g. ·900, contains 26 p.c. of the gas; it gradually becomes weaker from the escape of the gas, and should be kept in a cool place in well-stoppered bottles. Is too strong for medical use. Vesicates rapidly when held in contact with the skin; is an irritant poison; *antidotes,* weak acids and oils. When its vapour is inhaled it produces much irritation, which may be relieved by the steam of vinegar. Its *incompatibles* are those generally of potassa and soda.

(*b*) *Aqua Ammoniæ.* *Prep.*—By heating a mixture of sal ammoniac and lime in excess; the gas is absorbed by distilled water, $NH_4Cl+CaO=NH_4\overset{\uparrow}{O}+CaCl_{\rightarrow}$. In the officinal process the lime is slaked and made into a paste with water, which is further diluted before the addition of the NH_4Cl; the process on the moderate scale is thus much facilitated. It contains about 10 p. c. of ammonia.

Prop.—A colourless liquid, s. g. 0·959, having the smell and properties of ammonia. When neutralised with acetic acid, should not precipitate with carbonate of ammonia, $2NH_4O,3CO_2$ (absence of lime, etc.), nitrate of silver, AgO,NO_5 (absence of chlorides), or chloride of barium, $BaCl$ (absence of sulphates).

Med. Effects.—In large doses an irritant poison. In medicinal doses, gtt x to xxx, stimulant and antacid. Is administered and applied externally in snake-bites and stings of insects. Its vapour is inhaled in syncope and suspended animation. Is applied externally in burns and scalds, and as a rubefacient and vesicant.

(*c*) *Linimentum Ammoniæ*, volatile liniment, is made by mixing f℥j *Aquæ Ammoniæ* with ℥ij *Olei Olivæ*.

(*d*) *Spiritus Ammoniæ. Prep.*—By passing ammonia into alcohol; the strength is that of *aqua ammoniæ*. Is rarely used internally; it may be added to alcoholic liniments without decomposing them.

Spiritus Ammoniæ Aromaticus. Prep.—By dissolving ℥j *Ammoniæ Carbonatis* in f℥iij *Aquæ Ammoniæ* previously mixed with f℥iv *Aquæ;* to this is added a solution in *Alcohol* Oiss, of *Ol. Limonis* fʒiiss, *Ol. myristicæ* ♏xl, *Ol. Lavandulæ* ♏xv, and *Aquæ* q. s. ad Oij.

Prop.—An agreeable stimulant, aromatic antacid; dose, gtt xxx to fʒj, diluted. *Incompatible* with acids, acidulous and metallic salts. It probably contains neutral carbonate of ammonia, NH_4O,CO_2.

277. **Chloride**, NH_4Cl; *Ammonia Murias*, Sal ammoniac.

Prep.—By subliming a mixture of common salt, $NaCl$, and sulphate of ammonia, $NaCl+NH_4O,SO_3=NaO,SO_3\rightarrow +NH_4Cl\uparrow$. It may also be made by direct combination of gaseous HCl and NH_4O, and by the action of HCl on the carbonate or on gas liquor.

Prop.—White, inodourous, translucent, fibrous salt; taste pungent, saline. Soluble in three parts cold and one of boiling water; less so in ordinary alcohol. Sublimes unchanged at a red heat; very difficult to powder, unless in a hot iron mortar with a hot pestle. It may be granulated by evaporating its solution, and constantly stirring as the mass thickens. Reaction slightly acid.

Med. Effects.—Alterative; useful in hoarseness and sore throat, and is in these cases usefully combined with chlorate of potassa. Is given also in croup, bronchitis, neuralgia, intermittents, rheumatism, and enlarged prostate. Is applied externally to bruises. Dose, gr v to xxx.

278. **Carbonates**; *Ammoniæ Carbonas*, Carbonate of Ammonia, $2NH_4O,3CO_2$.

Prep.—Is made by subliming a mixture of NH_4Cl and chalk, $3NH_4Cl+3(CaO,CO_2)=2NH_4O,3CO_2\uparrow,+3CaCl+NH_4O$.

Prop.—White, moderately hard, translucent masses; soluble in four parts cold water, and in diluted alcohol; it is decomposed by boiling water. Smell pungent, ammoniacal; taste sharp, alkaline. Exposed to the air, it disengages neutral carbonate of ammonia (NH_4O,CO_2), and becomes *Bicarbonate* ($2NH_4O,3CO_2-NH_4O,CO_2=NH_4O,2CO_2$). The bicarbonate is inodourous and fixed; its crystals resemble those of bicarbonate of potassa. A neutral carbonate, NH_4O,CO_2, is known; it probably exists in *Spiritus Ammoniæ Aromat.*

Med. Effects.—A mild preparation, possessing the therapeutical properties of ammonia. Dose, gr v.

Incompatibles.—Those of the soluble carbonates and of ammonia.

279. The NITRATE of Ammonia is made by saturating HO,NO_5 with Carbonate of Ammonia; its crystals are isomorphous with those of KO,NO_5, which they much resemble in taste and appearance. Is used as a source of *nitrous oxide* (204).

280. **Sulphate,** NH_4O,SO_3; *Ammoniæ Sulphas.* Is obtained on the large scale from gas liquor; is not used in medicine, but largely employed in the manufacture of the preparations of Ammonia and in Ammonia *Alum* (302).

281. **Sulphur Salt,** NH_4S,HS, Sulphydrate of ammonia, hydrosulphuret of ammonia, bisulphide of ammonium, is made by passing a current of well-washed HS through *Aqua Ammoniæ fortior,* to saturation. The solution, nearly colourless at first, becomes yellow by keeping, and deposits sulphur. It exists in gas liquor, sewers, privies, etc. It has a fœtid odour. Is of the highest importance as a test, but is seldom used in medicine. It is properly termed sulphydrate of sulphide of ammonium; the sulphide of ammonium, NH_4S, a sulphur base being united to HS, a sulphur acid.

282. **Phosphate.**—None of the phosphates of ammonia are important; the tribasic phosphate of soda and ammonia, NaO,NH_4O,HO,PO_5, is used as a test for magnesia and in blowpipe analysis. Was formerly employed in medicine. It is known as *Microcosmic Salt,* or *Salt of phosphorus.*

283. **Acetate,** $NH_4O,C_4H_3O_3$, *Liquor Ammoniæ Acetatis,* Spirit of Mindererus.

Prep.—By saturating *Acid. Acetic. dilut.* (412); by Carbonate of Ammonia.

Prop.—Is a colourless inodorous liquid of a saline taste, and prone to change.

Med. Effects.—Is diaphoretic and diuretic; used in fevers, and externally as a cooling lotion; also as an antidote to alcohol. Dose, f℥ss to f℥iss. Is incompatible with the alkalies and alkaline earths, and the soluble salts of iron, copper, zinc, mercury, and silver.

284. **Valerianate**, $NH_4O,C_{10}H_9O_3$, *Ammoniæ Valerianas.*

Prep.—By saturating valerianic acid (414), $HO,C_{10}H_9O_3$, by gaseous ammonia.

Prop.—Snow-white, pearly, flat, four-sided crystals (2d system), volatilised, nearly unchanged by heat. Very soluble in water and alcohol.

Prop.—Is not poisonous; a powerful antispasmodic; used in hysteria, neuralgia, etc. May be given in pill or alcoholic solution; the watery solution rapidly decomposes. Dose, gr ij to viij. An *elixir* made by adding to the watery solution, cologne water, aromatics, and syrup, is much used.

CALCIUM, $Ca=20$.

Syllabus.

Oxide, CaO: (*a*) *Calx*; Hydrate, CaO,HO. (*b*) *Liquor Calcis.* (*c*) *Linimentum Calcis.* (*d*) *Potassa cum Calce.*

Chloride, $CaCl$: (*a*) *Calcii Chloridum;* (*b*) *Liquor Calcii Chloridi.*

Sulphides, CaS, CaS_2, CaS_5.

Fluoride, CaF, Fluor Spar.

Carbonates, CaO,CO_2; (*a*) *Calcis Carbonas Præcipitata;* (*b*) *Creta Præparata;* (*c*) *Testa Præparata.*

Sulphate, CaO,SO_3+2HO, Gypsum, Selenite, Alabaster.

Phosphate, $3CaO,PO_5$, *Calcis Phosphas Præcipitata.*

Hypophosphites, $CaO,2HO,PO$.

Hypochlorite, $CaO,ClO+CaCl+2HO$, *Calx chlorinata,* Bleaching Salt, Chloride of lime.

285. *Sources.*—Abundantly, in combination, in nature as carbonate in marble, *Marmor*, Chalk, *Creta*, Oyster-shell, *Testa*, etc.; as sulphate in Gypsum, as phosphate in bones, as silicate in many minerals, as chloride in certain mineral springs and sea-water, and as fluoride in fluor-spar.

Prep.—By electrolysis of its fused chloride.

Prop.—Resembles lead, but harder; has a yellowish colour; does not oxidise in dry air; fusible, but not volatile, at a red heat. Readily burns in the air with a brilliant light forming CaO. It also forms a binoxide, CaO_2, which is not a base; three sulphides, CaS, CaS_2, and CaS_5, and compounds with the halogens. The Phosphide, made by passing the vapour of P over red-hot lime, is brownish, and when thrown into water gives spontaneously inflammable phosphuretted hydrogen; it quietly crumbles to powder in moist air.

286. **Oxide,** CaO, (*a*) *Calx*, Lime.

Prep.—By heating the carbonate in a current of air; if heated in a close vessel, is fused and but slightly decomposed.

Prop.—A grayish-white solid; taste caustic, alkaline. S. g. 2·3; is very refractory. Absorbs on exposure to the air, water and CO_2, and falls to powder (air-slaked lime); combines with water, to form a hydrate (slaked lime). When mixed in excess with water, forms *milk of lime* (whitewash). Is sparingly soluble in water, and more so in *cold* than in *hot* water. Reaction, alkaline, is caustic; a strong base. *Mortar* is a mixture of sand or gravel with lime; the theory of its hardening is not well understood. *Hydraulic mortars*, which have the property of hardening under water, contain silicate of alumina (clay). Lime is much used in *agriculture*. It acts by neutralising acids, by decomposing organic matter, by liberating potassa from its combination with silica in clays and other rocks, and by furnishing the supply of lime compounds found in the plant.

Incompatibles.—Acids, acidulous salts, soluble sulphates, tartrates, carbonates; the metallic salts generally; the vegetable astringents. Is the *antidote* to OXALIC ACID.

Test.—Oxalic acid gives a white precipitate in neutral or alkaline solutions; sulphuric acid only in *concentrated* solutions.

(*b*) *Liquor Calcis;* Lime Water.

℞. *Calcis* ℥iv; *Aq. Destill.* Oviii. Slake the lime with a little of the water, then pour on the rest. Keep in well-stopped bottles over the insoluble excess of lime. Ordinary soft water will answer.

Rem.—Water at 60° dissolves about $\frac{1}{778}$ of lime; one pint contains, at 60°, about $9\frac{1}{2}$ grs.; when heated, a portion of the lime precipitates; the solution absorbs carbonic acid readily, and an insoluble carbonate precipitates.

Med. Effects.—Antacid, and the compounds formed by its union with the gastric acids, are *astringent.* Used in diarrhœa, vomiting, dyspepsia, etc.; externally as an astringent lotion. Dose, f℥ss to f℥iv.

(*c*) *Linimentum Calcis.* ℞. *Liq. Calcis* f℥viii, *Olei Lini* ℥vij. M. Used in burns and scalds.

(*d*) *Potassa cum Calce,* Vienna Paste.

Prep.—Is made by rubbing together equal parts of lime and caustic potassa; is deliquescent, but less so than the latter; is employed in the same cases, and is a milder application.

287. **Chlorides,** *Calcii Chloridum,* Chloride of Calcium, $CaCl$.

Prep.—Is made by dissolving carbonate of lime in hydrochloric acid. $CaO,CO_2+HCl=CaCl+HO$ and $CO_2\uparrow$.

Prop.—When anhydrous is a whitish, hard, translucent substance, having a great attraction for moisture; is used largely as a desiccating agent, and when crystallised in frigorific mixtures; taste acrid, bitter; reaction slightly alkaline; soluble in about $\frac{1}{15}$ its weight of water, at 60°; also in 10 parts anhydrous alcohol. The crystals contain 6 equivalents of water of crystallisation.

Incompat.—Those of the salts of lime, and of the soluble chlorides.

Med. Effects.—Tonic and alterative; used in solution.

Liquor Calcii Chloridi, Solution of Chloride of Calcium, is made by dissolving chloride of calcium in its weight and a half of water, and filtering. *Dose*, gtt xxx to ʒj; in overdose, may produce symptoms of irritant poisoning; *antidotes*, the carbonates or sulphates.

Carbonates.

(*a*) *Calcis Carbonas Præcipitata.* ℞. *Liq. Calcii Chlorid.* Ovss; *Sodæ Carb.* ℥lxxii (℔vi); *Aq. Destill.* q. s. Dissolve the *Sodæ Carb.* in Ovi *Aquæ;* heat this solution, and that of *Calcii Chlorid.*, to the boiling-point, and mix them; allow the carbonate to subside, wash it well, and dry on bibulous paper. $(CaCl+NaO,CO_2=CaO,\underset{\downarrow}{CO_2}+NaCl\rightarrow.)$

Prop.—An insoluble white powder, smooth, and entirely dissolved with copious effervescence in Muriatic acid. May be adulterated with CaO,SO_3, which is detected by thus treating it.

(*b*) *Creta Præparata.*

Prep.—Is made by the *levigation* and *elutriation* (191) of ordinary chalk, by which the grosser and gritty particles are gotten rid of.

Prop.—Found in conical masses, smooth, and entirely free from grit.

Med. Effects.—Internally, antacid and astringent; externally, a desiccating and soothing application. *Dose*, gr x to xxx.

(c) *Testa Præparata.*

Prep.—Is made by treating well-washed oyster-shells in the same manner as chalk; does not differ from *Creta Præparata*, except in containing a little animal matter.

288. **Sulphate**, CaO,SO_3+2HO.

Is found native, crystallised in right rhomboidal prisms (4th system) as *selenite*, which has the power of doubly refracting light; fibrous as *gypsum* and massive as *alabaster*. When heated it loses 20 p. c. of water, (calcined plaster, plaster of Paris) with which it will again unite, forming a plastic mass which soon solidifies; hence is used for making *casts*. At a red heat becomes anhydrous and will not again combine with water; it forms the greater part of the incrustations (scale) of steam-boilers. Is soluble in 500 parts of cold water; the addition of the chlorides of ammonium or tin increases its solubility. Is so soft as to be scratched with the nail; s. g. 2·92; gives to water permanent hardness (188). Is used in agriculture; being decomposed by the carbonates of the alkalies, it fixes the ammonia which arises as carbonate from manures and forms carbonate of lime, $CaO,SO_3+NH_4O,CO_2=CaO,CO_2+NH_4O,SO_3$. It is not employed in medicine.

289. **Phosphate**, $3CaO,PO_5$.

Calcis Phosphas Præcipitata.—*Prep.*—Dissolving calcined bone in HCl, diluted with its bulk of water, and filtering, precipitating the solution with *Liq. Ammoniæ* and washing the precipitate thoroughly with boiling water.

Prop.—A white powder without taste or smell, insoluble in water, but dissolved in HO,NO_5, HCl,HO,PO_5, and $HO,C_4H_3O_3$ (acetic acid), from which it may be precipitated unchanged by caustic alkalies.

Med. Effects.—Used in scrofula, phthisis, rachitis, and other diseases supposed to be dependent upon a deficiency of phosphates or of phosphorus in the system; dose, gr x to xxx; is probably rendered soluble by the gastric acids, or may be dissolved by the addition of the acids above named. Is the basis of the so-called *chemical food.*

290. **Hypophosphite,** CaO,2HO,PO. Is prepared by boiling milk of lime and P together; inflammable phosphuretted hydrogen is evolved; the clear liquid is decanted, filtered, and crystallised. $3(CaO,HO)+P_4+6HO=(3CaO,2HO,PO,)+PH_3$ (approximately). Is a pearly, white salt, soluble in 6 parts cold water. Has been employed in phthisis, scrofula, impotence, and other affections in which phosphorus is supposed to be indicated. *Dose, gr* v to x t. d. in water with syrup. Is not officinal.

291. **Hypochlorite,** *Calx Chlorinata,* Bleaching Powder, Chloride of Lime, $CaO,ClO+CaCl+2HO$.

Prep.—Made by the action of Cl on CaO,HO; $(2CaO,HO)+Cl_2+\overline{CaO,ClO+CaCl+2HO}$; should contain at least 25 per cent. of chlorine.

Prop.—Grayish-white powder; taste hot, acrid, bitter, and astringent; smell characteristic; bleaches powerfully; speedily loses its chlorine when kept; is decomposed on exposure to the air, absorbing CO_2, which liberates Cl; the same effect is produced by acids generally; soluble in 10 parts water; when heated it gives off O.

Med. Effects.—Not much used internally, the *Liq. Sodæ chlorinatæ* being preferred; used largely as a deodouriser, and as a stimulant wash. It acts chiefly by the liberation of its chlorine.

MAGNESIUM, $Mg=12$.

SYLLABUS.

OXIDE, MgO, *Magnesia.*

CARBONATE, *Magnesiæ Carbonas*, $4(MgO,CO_2),+MgO,HO+6HO$ (variable).

SULPHATE, MgO,SO_3+6HO, *Magnesiæ Sulphas*, Epsom salt.

CITRATE, $3MgO,C_{12}H_5O_{11}$, *Liquor Magnesiæ Citratis.*

Sources.—In sea-water as $MgCl$ and MgO,SO_3; in Dolomite, MgO,CO_2+CaO,CO_2, Magnesite, MgO,CO_2; in the native silicates as serpentine, hornblende, asbestus, steatite, (talc, soapstone,) etc.

Prep.—By the reaction of sodium and $MgCl$ at a high temperature.

Prop.—A silvery, white, ductile, malleable metal, s. g. 1·74, fusible and volatile at a red heat, does not readily oxidise in dry air nor decompose water; burns with a brilliant bluish-white flame forming MgO, its only oxide. It resembles zinc, with which its salts are isomorphous. The light of burning Mg wire has been employed for taking photographs, and in some cases to aid in speculum examinations.

292. *Magnesia*, MgO, Calcined Magnesia.

Prep.—Made by heating *Carbonate of Magnesia* to a full red heat, in an open crucible; the carbonate loses its carbonic acid and water, and anhydrous magnesia remains; may be precipitated as hydrate by the action of caustic alkali on its sulphate.

Prop.—An insoluble, light, white bulky powder, nearly insipid, fused only by the compound blowpipe; it should not effervesce with acids (absence of CO_2), nor precipitate with $BaCl$ (absence of sulphates). It forms a hydrate with water without perceptible elevation of temperature. Its reaction is feebly alkaline; it slowly attracts moisture and CO_2 from the air. *Dense* Magnesia (Henry's, Husband's, etc.) is from $\frac{1}{3}$ to $\frac{1}{4}$ the bulk of ordinary magnesia, and is less rough to the taste; it may be produced, 1. By trituration; 2. By using a high heat during calcination; 3. By packing the carbonate closely in the crucible before heating; 4. By heating just below redness the carbonate prepared by mixing hot concentrated solutions of sulphate of magnesia and carbonate of soda (Barr); 5. By heating chloride of magnesium. The fourth method is the best.

Tests.—Is precipitated from its salts as hydrate by the caustic alkalies, and as carbonate by their carbonates, but not by carbonate of ammonia, or the bicarbonates; a white crystalline precipitate is formed with the soluble phosphates on the addition of a little ammonia (ammonio-magnesian phosphate).

Med. Effects.—Antacid; the salts formed are laxative; from its low equivalent has a high neutralising power. The freshly prepared hydrate is an *antidote* to *arsenious acid.*

Incompatibles.—All acids and acidulous salts; neutral salts of the heavy metals.

293. **Carbonate,** *Magnesiæ Carbonas,* Magnesia Alba.

Prep.—On the large scale by double decomposition of sulphate of magnesia and carbonate of soda, carbonate of magnesia and sulphate of soda resulting, $MgO,SO_3+NaO CO_2=MgO,\underset{\downarrow}{C}O_2+NaO,SO_{3\rightarrow}$. Its composition is not constant, being a mixture of carbonate and hydrate of magnesia, $4(MgO,CO_2)+MgO,HO+6HO$. The native carbonate, MgO,CO_2, *magnesite,* and the double carbonate of lime and magnesia, MgO,CO_2+CaO,CO_2, *dolomite,* are not employed directly in medicine.

Prop.—A white, insoluble, smooth, nearly insipid, inodorous solid; generally found in small cubes; it is soluble to a certain extent in *Aqua Acidi carbonici*, forming the so-called *fluid magnesia*. It is decomposed by heat. *Impurities.* May contain carbonate or sulphate of soda; chloride of sodium, lime, alumina, iron; which may be detected by their respective tests.

Med. Effects.—Those of magnesia. The carbonic acid is liberated in the stomach.

Incompatibles.—Those of MgO and of the carbonates.

294. **Sulphate**, *Magnesiæ Sulphas*, $MgO,SO_3 + HO$, Epsom Salt.

Prep.—Occurs native in certain caverns in the United States, and as an efflorescence in the soil; also in certain springs, and in sea-water (*bittern*), from which it is prepared by evaporation and careful crystallisation. Made also from *dolomite, magnesite,* and from the native silicious hydrates.

Prop.—Transparent, inodorous, bitter, nauseous, neutral, oblique rhombic prisms (4th system, sometimes in the 3d); soluble in an equal weight of water at 60°; they melt in their own water of crystallisation, which they lose at a high heat, and then fuse into an enamel.

Impurities.—Iron and chloride of magnesium.

Med. Effects.—Mild cathartic. Dose, ℥ss to ℥i. *Incompatibles.* Those of the soluble sulphates; the alkalies and their carbonates.

295. **Citrate**, $3MgO,C_{12}H_5O_{11}$, *Liquor Magnesiæ Citratis.*

Prep.—Dissolve gr. cccl (ʒvij, gr. xxx) *acidi citrici* in f℥iv *Aquæ*, and add *Magnesiæ* gr. cxx (ʒij), and stir until dissolved. Filter the solution into a strong f℥xii bottle, and add *Syrupi Acid. citric* f℥ij; then add *Potassæ bicarb.* gr. xl, and *Aquæ* q. s. The bottle must be immediately corked, and the cork secured by twine. This is a solution of citrate of magnesia with excess of citric acid, which renders it more permanent. The *Potass. bicarb.* reacts with a portion of this excess to develop CO_2, which charges the liquid and renders it effervescent when opened. Is a most excellent, prompt, and agreeable saline cathartic.

BARIUM, Ba=68·5.

296. *Sources.*—Native carbonate (witherite), and sulphate (heavy spar).

Rem.—Is prepared like Mg. Is unimportant as a metal; s. g. 1·5; decomposes water at ordinary temperatures. It forms two oxides, BaO, baryta, and BaO_2, binoxide of Ba; the latter yields the second eq. of O, readily in the form of ozone (antozone?). The protoxide forms a hydrate, BaO,HO, with evolution of heat; this dissolves in 20 parts cold or 3 of boiling water, and forms a very delicate test for CO_2. The *nitrate* BaO,NO_5 is used in pyrotechny to communicate a green colour to flame; also as a test for sulphuric acid. The salts of baryta are poisonous; *antidotes*, the soluble sulphates (Epsom or Glauber's salt). The *chloride* may be obtained by the action of HCl upon $BaO,CO_2=BaCl+CO_2\uparrow$; it is used, like the nitrate, as a test, and is officinal in the *Liquor Barii Chloridi:* **℞**. *Barii chlorid.* ℥j, *Aquæ destillatæ* f℥iij, M. *et filtra.* Dose, gtt v t. d. Is considered alterative and anthelmintic. *Incompatibles,* the soluble sulphates, tartrates and oxalates, nitrate of silver, salts of lead and mercury.

STRONTIUM, Sr=43·7.

297. *Prep.*—In same manner as Ba, which it closely resembles.

Rem.—Forms *strontia*, SrO, and binoxide of strontium, SrO_2. Its salts give a red tinge to flame. They precipitate with the soluble sulphates, but less completely than those of Ba. May be distinguished by hydrofluosilicic acid, which precipitates BaO, but forms a salt with SrO, soluble in excess of acid. The preparations are not poisonous, and have been used in medicine with the same objects as those of Ba.

ALUMINUM, $Al''=13{\cdot}7$.

298. *Sources.*—In combination in clays, granitic rocks, and various minerals.

Prep.—By passing the vapour of chloride of aluminum over sodium at a red heat, $Al_2Cl_3+3Na=3NaCl+Al_2$, or by heating cryolite with sodium, $Al_2F_3,3NaF+3Na=6NaF+Al_2$.

Prop.—A white, tenacious, malleable, ductile metal of the hardness of silver, s. g. 2·56; fuses above a red heat; tarnishes in moist air; is not blackened by HS. Is not acted on by cold HO,SO_3, or HO,NO_5, but readily dissolves in HCl, forming Al_2Cl_3. Is acted upon also by alkaline solutions. Its alloys are remarkable for strength, lightness, and sonorousness; that with copper, *aluminum bronze*, has a permanent golden colour. The metal forms but one oxide, Al_2O_3, and its binary compounds are all of the same type.

299. **Oxide**, Al_2O_3, Alumina.

Prep.—Exists native in the sapphire, ruby, oriental topaz, and corundum. These bodies are not attacked by acids, and are inferior in hardness only to the diamond. It may be obtained by igniting *ammonia alum*, or the hydrate of alumina, $Al_2O_3,3HO$. This hydrate is obtained by precipitating its salts by caustic alkali. It occurs native in Gibbsite $Al_2O_3,3HO$, and Diaspore $Al_2O_3,2HO$.

Prop.—*Anhydrous*, a soft, white, tasteless, inodourous powder, without action on vegetable blues. The precipitated hydrate is a soft, gummy mass, like boiled starch, combining readily with acids and bases.

Chem. Rel.—Is like all sesquioxides a feeble base, its salts having an acid reaction; it combines also with bases acting as an acid (NaO,Al_2O_3). Its salts have a sweetish astringent taste, and are generally soluble in water. Alumina has a remarkable attraction for organic matter, it precipitates colouring matters from their solutions as *lakes;* is a powerful detergent and deodouriser. Is used largely in dyeing as a *mordant* (*bindermittel*, binding-medium, of the Germans). *Test.* Alkalies throw down a gelatinous hydrate freely soluble in acids.

Cotton impregnated with most organic colouring matters readily parts with them on washing. By using first a compound of aluminum, it adheres strongly to the fibre, also to the colouring matter, thus binding them firmly together. Binoxide of tin SnO_2, sesquioxide of iron Fe_2O_3, are also used as mordants.

300. **Sulphate,** $Al_2O_3,3SO_3+18HO$; *Aluminæ Sulphas.* Is obtained by dissolving freshly precipitated alumina in sulphuric acid. Is used as a detergent, deodouriser, and styptic.

301. **Alums.**

Alumina forms a series of double salts containing its sulphate with that of an alkali. They are types of a large class of compounds which have received the generic title of alums. Common potash alum is a double sulphate of alumina and potassa with 24 parts of water, $Al_2O_3,3SO_3+KO,SO_3+24HO$. We may replace the potassa by the oxides of sodium, ammonium, lithium, cæsium, and rubidium, and obtain salts hardly distinguishable from the potash alums. The alumina may be replaced by the isomorphous sesquioxides of iron, manganese, and chromium; in the latter case the alums are coloured, but otherwise resemble in every respect common alum. The following list will give an idea of the composition of these isomorphous double salts:

$$\begin{array}{ll}
Al_2O_3,3SO_3+ & KO,SO_3+24HO, \\
Cr_2O_3 & NaO, \\
Mn_2O_3 & NH_4O, \\
Fe_2O_3 & CsO.
\end{array}$$

We have also a series of minerals of the same type, in which SiO_3 replaces SO_3, but not isomorphous with the foregoing, as they are anhydrous; thus:

$Al_2O_3,3SiO_3+KO,SiO_3$, Feldspar.
$Al_2O_3,3SiO_3+NaO,SiO_3$, Albite.
$Al_2O_3,3SiO_3+LO,SiO_3$, Petalite.
$Al_2O_3,3SiO_3+CaO,SiO_3$, Labradorite.

Many others are known in which the proportions of the two salts vary, but the general type remains.

302. **Alumen**, Alum, $Al_2O_3,3SO_3+KO,SO_3+24HO$.

Prep.—Is made in various ways on the large scale, the principle of the process being to procure the sulphates of alumina and potassa, and crystallise them together.

In this neighbourhood alum is made at the oil of vitriol works by acting upon a pure white *clay* (silicate) with unconcentrated sulphuric acid, mixing with the sulphate of alumina thus obtained the sulphate of potassa remaining after the manufacture of nitric acid, and crystallising. By replacing the KO,SO_3 by NH_4O,SO_3, obtained from gas-liquor, *ammonia alum* is obtained.

Prop.—A colourless, slightly efflorescent salt, of a sweetish, astringent taste, crystallising in regular octohedra (1st system). It is soluble in 15 parts of cold and $\frac{3}{4}$ths its weight of boiling water. When heated, it fuses in its water of crystallisation, which is finally in great part driven off, the mass froths, swells, and forms a white porous mass,—dried alum, *alumen exsiccatum*.

Med. Effects.—Astringent, tonic, and antispasmodic; in large doses, emetic and purgative. Given internally in croup, as an emetic, in *colica pictonum*, etc. The *alumen exsiccatum* is a favourite mild escharotic. *Incompatibles.* The vegetable astringents, alkalies, and alkaline earths, tartrates, and those of the soluble sulphates.

Alum is largely used in dyeing, the preparation of skins, clarifying liquors (189), rendering wood and paper incombustible, and as a filling for iron safes.

Aluminæ et Ammoniæ Sulphas, Ammonia alum. *Prep.* Given above; it is used as a substitute for ordinary alum, from which it is distinguished by the ammonia evolved upon treating it with a caustic alkali. The *ammonio-ferric alum*, $Fe_2O_3,3SO_3+NH_4O,SO_3+24HO$, contains no alumina; it will be considered under IRON.

303. **Silicates**; Clay.

Clay is formed by the decomposition of rocks containing silicate of alumina; it is very variable in its composition, the red varieties containing iron, and most clays magnesia, lime, potassa, soda, etc. Pure clay—fire clay—is a normal silicate of alumina, $Al_2O_3,3SiO_3$. *Kaolin*, a white clay, used in making porcelain, contains Al_2O_3,SiO_3+2HO; *marls* contain phosphates and lime; *Fuller's earth* is a porous clay used for extracting grease.

Prop.—When moist, exhales a peculiar odour; is plastic, hence its value in the manufacture of porcelain, earthenware, etc. When dried it becomes hard and adheres to the tongue. In soils it possesses the property of absorbing large quantities of ammonia, and of decomposing the compounds of that base.

GLASS AND PORCELAIN.

304. *Glass* is a mixture of the silicates of potassa and soda with those of alumina, lime, and the metallic oxides. The silicates of the alkalies alone are soft, acted upon by water and chemical agents, and in some cases freely soluble in water; those of the other bases named will crystallise and thus lose their transparency; by admixture the faults of both are corrected. The composition of glass varies exceedingly; the following are the most important varieties.

Bohemian Glass.—Much prized for its hardness and resistance to chemical agents; contains 66 p. c. silica, 12 potassa, 9 lime, and 10 alumina. It is used in the laboratory as flasks and tubes, and in many ornamental and useful forms.

Crown Glass.—Resembles the Bohemian; is used in the plates of mirrors, large windows, lenses, etc.

Window Glass.—Used for common glazing, druggists' bottles, etc.; contains soda in place of potassa. It has a greenish tinge when in thick plates.

Flint Glass, used in lenses, prisms, and fine cut glassware; contains, in addition to potassa, oxide of lead (43 p. c.). It is dense, soft, easily fusible, and of a high refractive power.

Paste, or *strass*, used for imitating gems, is a flint glass containing a still larger proportion of lead.

Bottle Glass.—Contains oxide of iron, to which it owes its green colour. Is made of the cheapest materials; it contains but little alkali. Is not easily acted upon by acids or alkalies.

Soluble Glass.—Is a silicate of potassa or soda containing an excess of base. When powdered, it is freely soluble in boiling water. It is used as a detergent, as a fireproof varnish for wood, and as a cement.

Colours of Glass.—Soda glass has always a greenish tinge; the various metallic oxides communicate colours to glass; they may be incorporated with the glass in the melting-pot, or applied to its surface in the form of enamel or glaze (stained glass). *Green* is produced by protoxide of iron, FeO, or protoxide of copper, CuO; *blue*, protoxide of cobalt, CoO; *yellow*, by oxide of silver, AgO, and teroxide of antimony, SbO_3. The fluorescent *canary* glass is coloured by the sesquioxide of uranium, U_2O_3; *ruby red*, by oxide of gold, AuO, and suboxide of copper, Cu_2O; *amethystine*, purplish-pink, by binoxide of manganese, MnO_2; the same in large quantity, mixed with oxide of cobalt, CoO, a *black*. White enamel, used for watch-dials, is glass with oxide of tin, SnO; and an opalescent white glass, used for lamp-shades, contains arsenic. Black oxide of manganese is added in the manufacture of glass to take away its greenish tinge; this is done by oxidising any FeO present to Fe_2O_3, which does not colour; the manganese itself communicates a pinkish tint to the glass, which being complementary to the green neutralises it. It is hence called *glass-maker's soap*, or *pyrolusite* (Gr. *pur*, fire, and *luō*, I wash).

305. **Porcelain.**—The various grades of earthenware from the finest porcelain to the commonest red pottery are all formed by baking clay; the difference being in the quality of the clay and the methods of manufacture. For porcelain the finest *Kaolin* free from all iron is used; for common pottery, ordinary clay, the iron of which gives the well-known red colour. The articles, after being shaped while the clay is in a plastic condition, are baked, when they become hard but are porous, as in an ordinary brick or flower-pot; they are afterwards glazed. For porcelain a fine glazing of powdered feldspar and quartz is used; for stoneware, common salt, which at a high heat is decomposed and the soda formed unites with the silica of the stoneware. Common black glazing contains lead, and accidents may occur if acid liquids kept in dishes so glazed are afterwards used in food. The colours used in porcelain are the same as for glass. *Fire bricks* are made from a pure clay, free from all metallic oxides. *Hessian crucibles* are made of a mixture of clay and sand; they bear a high heat, but are apt to crack. Black-lead crucibles are made of a mixture of plumbago and clay; they will stand heat better than the former. In delicate chemical operations porcelain and platinum crucibles are used.

MANGANESE, Mn=27·8.

306. *Sources.*—The native black oxide, MnO_2, and carbonate. It is stated to exist in small quantity in the blood.

Prep.—By reducing MnO_2 at a high heat by means of carbon.

Prop.—A steel-gray metal, brittle, s. g. 8·00; on exposure to the air oxidises and crumbles to powder. It appears to possess feeble magnetic properties at low temperatures.

Chem. Rel.—Forms with O, MnO, a base, Mn_2O_3, a feeble base, MnO_2, a neuter body, MnO_3 manganic acid, and Mn_2O_7 permanganic acid. Its other binary compounds are of slight importance; the iodide has been employed in medicine; it may be made by the double decomposition of $MnO,SO_3+KI=MnI_{\rightarrow}+KO,SO_3$; it is made into a syrup like the *Syrup. Ferri. Iodid.* The salts of manganese have a delicate rose-colour. *Test.* Sulphydrate of ammonia gives a flesh-coloured characteristic precipitate; the salts communicate an amethystine tint to borax in the outer blowpipe flame.

307. **Oxides.**

The *protoxide* is obtained hydrated by the addition of KO,HO to $MnO,SO_3=KO,SO_{3\rightarrow}+\underset{\downarrow}{MnO},HO$. It is white, rapidly absorbing oxygen, and becoming sesquioxide. The anhydrous protoxide is of a dirty green colour; it rapidly absorbs O, and at 600° takes fire.

The sesquioxide, Mn_2O_3, is isomorphous with Al_2O_3; not important.

The BINOXIDE, MnO_2, *pyrolusite*, *Manganesii Oxidum nigrum*, is found native. It readily yields a portion of its O when heated. It does not unite with acids or bases; an acid added to it forms a salt of the protoxide with evolution of O, $MnO_2+HO,SO_3=MnO,SO_{3\rightarrow}+HO+O^{\uparrow}$. Is extensively used in the manufacture of chlorine, of glass, and the permanganates. It is officinal as *Manganesii Oxidum nigrum*, but is rarely used in medicine. Manganic acid, MnO_3, is not isolable. By heating MnO_2 with KO,NO_5 and KO,HO, KO,MnO_3 is formed. This is an uncrystallisable mass of a greenish colour (*chameleon mineral*); when thrown into water, it becomes purple and finally red from the formation of permanganate, KO,Mn_2O_7.

PERMANGANIC ACID is known only in combination with water or a base; it is rapidly decomposed by organic matters and other deoxidising bodies, becoming reduced to Mn_2O_3. See *Potassæ Permanganas* (309).

The compound oxides, red oxide Mn_3O_4, or MnO,Mn_2O_3, and varvicite $Mn_4O_7=2MnO,Mn_2O_3$, are unimportant.

308. *Manganesii Sulphas*, MnO,SO_3+5HO (at 60°).

Prep.—By gently heating MnO_2 with $HO,SO_3=MnO,SO_3+HO+O$, evaporating and crystallising. The quantity of water of crystallisation will depend upon the temperature of the latter operation.

Prop.—Rose-coloured rhombic crystals (3d system), very soluble in water, insoluble in alcohol; of a bitter, astringent taste. It may contain copper, iron, and arsenic. Should give no precipitate with infusion of galls, a flesh-coloured one with NH_4S,HS, and a white one with K_2Cfy.

Med. Effects.—In doses of ʒj to ʒij a cholagogue cathartic; in smaller doses, gr x to xx, has been used in conjunction with iron in anæmia.

309. *Potassæ Permanganas*, KO,Mn_2O_7.

Prep.—Is always made on the large scale; an outline of the method is given in § 307.

Prop.—In brilliant purplish-red, right rhombic crystals (3d system), soluble in 16 parts water at 60°; they explode when heated. They communicate an amethystine tinge to water when in very small quantity; the concentrated solution is of a deep red colour, permanent, and of a peculiar taste. When necessary, it may be filtered through gun-cotton; most other organic matters decompose it rapidly.

Med. Effects.—An excellent deodouriser. It probably acts by eliminating ozone, and thus destroying organic effluvia and compounds containing hydrogen. If exposed in solution (Condy's solution) in shallow vessels, it speedily purifies the air of a room, and will continue to act for a long time. Added to foul water, it renders it sweet, becoming at the same time reduced to MnO_2, which subsides, and KO, which remains in solution. Has been used externally in the treatment of various foul ulcers and offensive discharges, gangrene, diphtheria, etc. Also to remove the offensive odour of the armpits and feet, and that adhering to the hands after certain operations, post-mortem examinations, etc. Internally has been administered in cases where an oxidising agent is supposed to be indicated, and in zymotic diseases. It must be applied with a brush of asbestus, as it is decomposed by organic matter. A liquid containing one-tenth of a saturated solution is a convenient strength for ordinary uses. In large doses would prove an irritant poison, the antidote being albumen, milk, or similar organic matters. It is used in the laboratory as a reagent in volumetric analysis.

IRON, Fe=28.

SYLLABUS.

AS METAL: (*a*) *Ferrum;* (*b*) *Ferrum Redactum,* Quévennes iron.

OXIDE: *Ferri Oxidum Hydratum,* $Fe_2O_3,3HO$.

SULPHIDE, FeS; *Ferri Sulphuretum.*

CHLORIDE, Fe_2Cl_3: (*a*) *Ferri Chloridum*; (*b*) *Tinctura Ferri Chloridi,*—gr xxix to f℥j.

IODIDE, FeI: (*a*) *Syrupus Ferri Iodidi,*—gr xlviii to f℥j; (*b*) *Pilulæ Ferri Iodidi.*

Ferrocyanide, Fe_4Cfy_3, *Ferri Ferrocyanidum,* Prussian Blue.

NITRATE, $Fe_2O_3,3NO_5$; *Liquor Ferri Nitratis.*

CARBONATES: (*a*) *Pilulæ Ferri Carbonatis* (FeO,CO_2), Vallet's Mass; (*b*) *Mistura Ferri Composita,* and (*c*) *Pilulæ Ferri Compositæ* (contain FeO,CO_2); (*d*) *Ferri Subcarbonas* (Fe_2O_3,CO_2?); (*e*) *Trochisci Ferri Subcarbonatis.*

SULPHATES: (*a*) *Ferri Sulphas,* FeO,SO_3+7HO, Copperas, Green vitriol; (*b*) *Ferri Sulphas Exsiccata,* FeO,SO_3+HO; (*c*) *Liquor Ferri Tersulphatis,* $Fe_2O_3,3SO_3$; (*d*) *Liquor Ferri Subsulphatis,* $2Fe_2O_3,5SO_3$, Monsel's solution; (*e*) *Ferri et Ammoniæ Sulphas* ($Fe_2O_3,3SO_3+NH_4O,SO_3+24HO$), Ammonio-ferric alum.

PHOSPHATES: (*a*) *Ferri Phosphas,* $2FeO,HO,PO_5$; (*b*) *Ferri Pyrophosphas* (contains $2Fe_2O_3,3PO_5+9HO$).

LACTATE; *Ferri Lactas,* $FeO,C_6H_5O_5+3HO$.

TARTRATES: (*a*) *Ferri et Potassæ Tartras,* $Fe_2O_3,KO,C_8H_4O_{10}+HO$; (*b*) *Ferri et Ammoniæ Tartras,* $Fe_2O_3,NH_4O,C_8H_4O_{10}$.

CITRATES: (*a*) *Ferri Citras,* $Fe_2O_3C_{12}H_5O_{11}$; (*b*) *Liquor Ferri Citratis*—℥ss to f℥j; (*c*) *Ferri et Ammoniæ Citras,* $Fe_2O_3,NH_4O,C_{22}H_5O_{11}+2HO$, (*d*) *Ferri et Quiniæ Citras,* $Fe_2O_3,C_{40}H_{24}N_2O_4,C_{12}H_5O_{11}+4?HO$.

310. *Sources.*—The most important *ores* of iron are the Magnetic oxide, Fe_3O_4, Specular iron or red hæmatite, F_2O_3, Brown hæmatite, $Fe_2O_3,3HO$, Sparry carbonate, FeO,CO_2, and Clay iron stone, which also contains the carbonate. It exists abundantly as iron pyrites, FeS_2, which is not used as an ore; in soils, rocks, mineral springs, the

hæmatine of the blood, etc. Is the most abundant and widely diffused of the heavy metals. Is found very rarely native; occurs combined with nickel in meteoric stones.

Prep.—Iron ores are reduced in the blast furnace by means of carbon; lime-stone is added to act as a *flux*—that is, to combine with the silica of the ores, which would otherwise unite with the iron; the *slag* formed by the silicate of lime floats on the surface of the reduced iron, and is taken from the lower part of the furnace by a separate opening. *Cast iron*, the product of the blast furnace, is a carbide containing as high, in some cases, as 5 p. c., which would give Fe_4C. It also contains graphite, uncombined carbon, silica, and often sulphur and phosphorus; the latter are exceedingly difficult to remove and injurious to its quality, sulphur rendering iron brittle when hot (red short) and phosphorus when cold (cold short). *Wrought iron* is made by burning the carbon out of cast iron by a current of air (puddling). It may be obtained pure by reducing pure Fe_2O_3 by a current of H at a red heat (*Ferrum redactum*). *Malleable iron*, so called, is manufactured by keeping plates or articles made of cast iron imbedded in hæmatite or oxide of zinc, at a red heat, for a long time. The iron loses a part of its carbon, and resembles in many respects wrought iron. *Steel* contains from 1·3 to 1·75 p. c. of carbon. It is prepared (1) by partially decarbonising cast iron (puddled steel); (2) by exposing bars immersed in charcoal powder to an intense heat for 48 hours or more (blistered steel). The latter process is termed *cementation*.

Prop.—*Cast* iron is of a grayish-white appearance, s. g. 7·207, melts at a white heat, and in small masses burns. It expands on cooling. Wrought iron is infusible, but at a white heat becomes pasty and may be welded; it is malleable, and one of the most ductile and tenacious of metals,

s. g. 7·780. It has a silvery, metallic lustre, which soon tarnishes. Steel has a s. g. of 7·850, is more tenacious than iron, and has the remarkable property of becoming hardened when heated to redness and suddenly cooled; by reheating and slowly cooling, this hardness is diminished (*drawn down*), and the steel is said to be *tempered*. It is then highly elastic, malleable and ductile. Iron and steel possess magnetic properties, which they lose when heated to redness. All the forms of iron rust when exposed to moist air or when immersed in ordinary water. The presence of a small portion of acid, or of certain salts, increases greatly this change, and the presence of alkalies and lime in water retards it. Iron does not rust in water deprived of air. Cast iron long immersed in sea-water has the iron entirely removed, leaving a mass of carbon. Rust consists of hydrated sesquioxide, $Fe_2O_3,3HO$, and always contains NH_4O, from the union of atmospheric N with the nascent H given off during oxidation. When iron is burned, the magnetic or black oxide Fe_3O_4 is formed.

311. *Passive Condition of Iron.*—Iron is usually readily attacked by acids, but may be rendered *passive*, in which state it is not affected by concentrated nitric acid. This condition may be brought about (1) by heating the iron and plunging into HO,NO_5; (2) by dipping it in HO,NO_5 and washing with water; (3) by putting it in contact with a platinum wire or piece of passive iron immersed in the acid; (4) by making it the positive pole of a voltaic circuit, introducing it after the negative. These curious results appear to depend upon the formation of a film of oxide. Passive iron is employed as a cheap substitute for platinum in the nitric acid battery (98).

312. *Chem. Rel.*—Iron unites with most of the metals, and with all the non-metallic elements, except H? and B. It forms with O, 1. *Protoxide*, ferrous oxide, FeO, which may be obtained by precipitating a salt of the protoxide with a caustic alkali; it forms a whitish hydrate, losing its water, and becoming black, when boiled; is attracted

by the magnet; exposed to the air, turns green, and ultimately brown, absorbing O and becoming sesquioxide; when dry, it sometimes absorbs O with such avidity as to take fire; is powerfully basic. Its salts are generally of a delicate green colour, and nauseous, metallic taste; they absorb oxygen readily, except the native carbonate, becoming brown, from the formation of sesquioxide. 2. *Sesquioxide, Ferric oxide, Colcothar, Crocus Martis, jewellers' rouge*, Fe_2O_3, prepared by precipitating a salt of the sesquioxide by caustic alkali, and igniting the hydrate thus formed, is of a red colour, not attracted by the magnet, unaltered by heat, reduced by a current of hydrogen at a red heat, or by C at a higher heat; is feebly basic when hydrated, inert when anhydrous. Its salts, formed generally by oxidising those of the protoxide, have a reddish or brown colour, a styptic, astringent taste, and an acid reaction. It is reduced by vegetable matter, the protoxide formed again absorbing O from the air and carrying it to the fabric Thus the corrosive effect of rust or iron mould is accounted for. Like alumina, it acts as a mordant, and it renders the colours darker. 3. *Black Oxide, Magnetic Oxide*, Fe_3O_4, most probably a combination of FeO,Fe_2O_3, does not form salts. Ferric Acid, FeO_3, has not been isolated; its potassa salt forms a deep amethystine-red solution, which soon decomposes; it forms with baryta a deep crimson, insoluble, permanent salt; with S, FeS (*Ferri Sulphuretum*), Fe_2S_3, FeS_2, iron pyrites, and Fe_7S_8, magnetic pyrites. Iron pyrites, FeS_2, occurs in cubes or octohedra (1st system) of a brassy appearance, and so hard as to strike fire, hence its name (Gr. *pur*, fire). It is easily distinguished from gold [illegible] its hardness and its lower s. g. 4·7, and the SO_2 evo[illegible]n it is heated. Exposed to m[illegible] air, when mixe[illegible]tosulphide, as in various s[illegible]latter absorb[illegible]ing considerable heat, and becoming FeO,SO_3, which is thus sometimes manufactured.

There are two varieties of common pyrites generally described; the hepatic, which is of a liver-colour, appears to be only common pyrites partially oxidised. We have also two varieties of arsenical pyrites.

The other important compounds of iron will be considered under their officinal preparations.

Tests.—For the protoxide: Ferricyanide of potassium, K_3Cfdy, throws down a blue precipitate (Fe_3Cfdy, Turnbull's blue). For the sesquioxide: (1) Infusion of galls, a black precipitate (ink); (2) Ferrocyanide of potassium, K_2Cfy, a blue one (Prussian blue, Fe_4Cfy_3); (3) Sulphocyanide of potassium, $KCsy$, strikes a blood-red colour; (4) HS gives a white precipitate of S; and (5) NH_4S,HS, a black one of FeS.

Med. Effects.—The salts of iron are tonic and astringent, the former property being possessed more decidedly by the *proto* compounds conveniently termed *ferrous* salts, and the latter by the *sesqui*, or *ferric* salts. It is deficient in the blood in anæmia. The blackening of the stools observed during the internal use of iron is due to the formation of sulphide.

Incompatibles.—The vegetable astringents, the alkalies, alkaline earths, and their soluble carbonates. The members of the cyanogen group generally.

313. **As Metal.**—*Ferrum Redactum*, Quêvennes iron.

Prep.—By passing a current of H at a red heat over *Ferri subcarb.*, which may be regarded in many cases as merely a sesquioxide, $Fe_2O_3+H_3=Fe+3HO$.

Prop.—A light tasteless iron-gray powder, having the properties otherwise of iron. It readily absorbs moisture from the air and oxidises; hence it should be kept in well-

ttles. Dose, gr j to iij; is readily administered in lozenges, etc. It causes eructations of H. Is *incompatible* with acids and acid salts.

314. **Oxide**, *Ferri Oxidum Hydratum*, $Fe_2O_3,3HO$.

Prep.—By adding to Oj *Liq. Ferri Tersulphatis*, previously mixed with Oiij *Aquæ*, *Aqua Ammoniæ*, until in slight excess; the precipitate is separated by a wet muslin strainer and washed, $Fe_2O_3,3SO_3+3(NH_4O,HO)=Fe_2O_3,\underset{\downarrow}{3HO}+3(NH_4O,SO_3)\rightarrow$. In the absence of the *Liq. Ferri Tersulphat.*, the *Tinct. Ferri Chlorid.* may be used, $Fe_2Cl_3+3(NH_4O,HO)=Fe_2O_3,\underset{\downarrow}{3HO}+3NH_4Cl\rightarrow$. Monsel's solution (321), or any soluble ferric salt, will yield the ferric hydrate on the addition of alkali.

Prop.—A brownish pulpy mass, freely soluble in acids; when long kept, undergoes a change, becoming crystalline, and losing one-half of its water; its virtues as an *antidote* are then impaired; it also quickly becomes crystalline when frozen; immediately, at 21° (Limberger); does not, however, then lose its water, as when long kept, and although less soluble than the amorphous, is more so than that which has become crystalline, and less hydrated by long keeping (Wittstein).

Med. Uses.—Used sometimes as a tonic; most valued as an antidote to ARSENIOUS ACID.

315. **Sulphide**, *Ferri Sulphuretum*, FeS, or $(5FeS+Fe_2S_3)$.

Prep.—By heating together Fe and S. 1. A mixture of two parts of S and one of Fe by weight. 2. By rubbing roll sulphur upon the end of an iron rod heated to redness and allowing the fused mass to fall into water. It generally contains an excess of S, but when heated to expel this, is a protosulphide (ferrous sulphide), FeS. Has a brownish-black colour; evolves HS on exposure to moist air. Is used only for making sulphydric acid, HS (217).

316. **Chloride**, *Ferri Chloridum, Tinctura Ferri Chloridi.*

Prep.—Take of pieces of iron wire (card-teeth are convenient) ℥ij, *Acid. Muriatic* ℥xii, *Acid. Nitric.* ℥j or q. s. Add the iron to ℥viij of the *Acid. Muriat.* in a large flask, and heat gently until effervescence ceases; filter, add the remainder of the *Acid. Muriat.*, heat nearly to boiling, and add the *Acid. Nitric.* by degrees until red fumes are no longer evolved and the liquid does not afford a precipitate with ferricyanide of potassium, K_3Cfdy (absence of ferrous chloride). Evaporate and crystallise.

Remark.—Iron forms a *ferrous* chloride, when acted upon by HCl; $Fe+HCl=FeCl+H$. It is a greenish liquid, prone to change. By the action of the HO,NO_5 and HCl this is converted into the *ferric* chloride, $6FeCl+HO,NO_5+3HCl=3Fe_2Cl_3+NO_2+4HO$.

Prop.—In orange-yellow grains of a crystalline structure which varies with the amount of water of crystallisation. Is rarely used in the solid form. In solution is employed as a styptic and deodouriser.

Tinctura Ferri Chloridi; Muriated Tincture of Iron. ℞. *Ferri*, ℥iij; *Acid. Muriat.*, ℥xviiss; *Alcohol*, Oiij; *Acid. Nitric, Aquæ Destillatæ*, āā q. s. Proceed as in the last preparation, but instead of crystallising add the aqueous solution, which should measure Oj, to the alcohol. It was formerly prepared by the action of HCl on *Ferri subcarb.*, $Fe_2O_3,3HO+3HCl=Fe_2Cl_3+6HO$.

Prop.—A transparent, reddish-brown liquid of a styptic, sour taste and agreeable fruity odour, s. g. 0·990, contains 29 grs to f℥j. Is used as a specific in erysipelas and spasmodic stricture. Is incompatible with gum arabic. Dose, gtt x to xxx gradually increased; should be diluted with water and sucked through a tube to avoid action on the teeth.

317. **Iodide**, FeI; *Syrupus Ferri Iodidi.*

Prep.—Introduce into a thin glass flask ℥ij *Iodinii*, *Ferri fili** gr ccc., *Aquæ destillatæ* f℥iij; agitate until the liquid acquires a green colour and loses the smell of iodine. .Then filter into it Oj *Syrupi* previously heated to 212°; shake thoroughly, and when cool add *Syrupi* q. s. *ad* f℥xxii. The iron is in excess; the sugar protects the iodide from change; without it the iron becomes oxidised and the iodine set free, giving a brownish tinge to the liquid; iron wire in the liquid will again combine with this. It should be kept in the dark.

Prop.—A transparent, greenish liquid, which should not affect starch (absence of free iodine). Has the medical properties of its constituents. Dose, gtt xx to xl, dropped into water in a glass or porcelain vessel. Like the *Tinct. Ferri Chlorid.*, should be taken through a glass tube, or quill.

Pilulæ Ferri Iodidi, Blancard's Pills.

Prep.—℥ss *Iodinii*, gr ccxx *Ferri fili* and f℥j *Aquæ*, are mixed as above, and filtered upon a mixture of *Altheæ pulv.* ℥ss, *Acaciæ pulv. et Ferri Redacti* āā gr lx; fʒij *Aquæ destillat.* being poured upon the filter to wash it. Evaporate with stirring to a pilular consistence, and make 300 pills. These are coated by shaking in a solution of *Balsam. Tolutani* gr lxj in fʒj *Ætheris*, and drying. Each pill contains about gr j *Ferri Iodid.* and $\frac{1}{5}$ gr *Ferri Redacti.* They are quite permanent.

318. **Ferrocyanide**, *Ferri Ferrocyanidum*, Prussian Blue, Fe_4Cfy_3.

Prep.—By adding gradually with stirring to a solution of *Potass. Ferrocyanid.* ℥ix in Oij *Aquæ*, Oj *Liq. Ferri Tersulphatis* diluted with Oj *Aquæ*, and washing the precipitate with boiling water; $3K_2Cfy+2(Fe_2O_3,3SO_3)=Fe_4\underset{\downarrow}{Cfy_3}+6(KO,SO_3)_{\rightarrow}$. Soluble Prussian Blue (not officinal) is made, (1) by exposing the white precipitate obtained from a ferrous salt by K_2Cfy to the air, $(Fe_4Cfy_3+Fe_2O_3)$; (2) by adding $Fe_2O_3,3NO_5$ to an excess of K_2Cfy, and washing, $(Fe_4Cfy_3+2K_2Cfy)$. Both of these dissolve in pure water.

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* Iron wire, card teeth.

Prop.—The officinal ferrocyanide is a deep blue, tasteless, inodorous powder, insoluble in water and alcohol. Is used in dyeing, painting, and when dissolved by the aid of oxalic acid, HO,C_2O_3, forms blue ink. Has been used as an antiperiodic and in neuralgia. Dose, gr v to x, gradually increased.

319. **Nitrates,** *Liquor Ferri Nitratis*, $Fe_2O_3,3NO_5$.

Prep.—By the action of dilute HO,NO_5 in excess upon iron.* At first a *ferrous* nitrate is formed, which has a pale colour and is prone to decomposition, $Fe+HO,NO_5=FeO,NO_5+H$. This is employed in medicine when protected by syrup, but is not officinal. The *ferrous* nitrate, heated to 130° with the gradual addition of HO,NO_5, becomes *ferric* nitrate, $6(FeO,NO_5)+4(HO,NO_5)=3(Fe_2O_3,3NO_5)+NO_2+4HO$; s. g. 1·060 to 1·070. It contains ℥j *Ferri* to f℥xxxvi of solution.

Prop.—An amber-coloured liquid of an acid, astringent taste. Used especially in chronic diarrhœa, unattended by ulceration.

320. **Carbonates.**

Rem.—An alkaline carbonate added to a ferrous salt throws down a white hydrated ferrous carbonate, FeO,CO_2; on exposure to the air this absorbs O, and loses CO_2, becoming F_2O_3 with a varying proportion of CO_2.

Pilulæ Ferri Carbonatis, Vallet's Mass.

Prep.—℞. *Ferri Sulph.* ℥viii; *Sodæ Carb.* ℥ix; *Mel. Despum.* ℥iij; *Sacch. pulv.* ℥ii; *Aq. Bull.* Oij; *Syrup.* q. s. Dissolve the sulphate of iron and carbonate of soda, each in Oj of water, to which has been previously added f℥j syrup; mix the two solutions, pour into a bottle, closely stopped, just large enough to hold them, and allow the precipitate to subside, ($FeO,SO_3+NaO,CO_2=\underset{\downarrow}{FeO,CO_2}+NaO,SO_3\rightarrow$); pour off the supernatant liquor; wash the precipitate with water recently boiled and sweetened with syrup (f℥j to Oj), until the washings have no longer a saline taste; place it upon a flannel cloth to drain, and afterwards express as much water as possible; then immediately mix with the honey and sugar; by means of a water-bath evaporate with constant stirring to a pilular consistence.

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* Excess of water is omitted in the reactions. See p. 128.

Rem.—The use of the sugar is to protect the *ferrous* carbonate, FeO,CO_2, from change. An efficient and easily administered chalybeate. Dose, gr v to x. The *Mistura Ferri Composita* and *Pilulæ Ferri Compositæ* contain FeO,CO_2; they are liable to change, and but rarely prescribed.

Ferri Subcarbonas, Precipitated carbonate of iron.

Prep.—As above, but without the use of syrup, the precipitate is washed with water and dried on unsized paper, *without heat.* The FeO,CO_2 at first precipitated absorbs O, turns reddish-brown, and loses a great part of its CO_2. The preparation is a hydrated sesquioxide containing some CO_2.

Prop.—A reddish-brown powder, soluble freely with effervescence in HCl, with difficulty in other acids. When heated, it loses water, becomes of a brighter red, and is injured; by high heat it becomes anhydrous Fe_2O_3 which is not attacked by acids or alkalies, and is inert, (colcothar, jeweller's rouge). When prepared as directed, may be used, in the absence of the *Ferri Oxid. Hydrat.*, in cases of poisoning by AsO_3. Is given in doses of gr x to xx as a tonic, and in large doses up to ℥j as an antispasmodic. The *Trochisci Ferri Subcarbonatis* contain each about gr v.

321. Sulphates.

Ferri Sulphas, Ferrous sulphate, Copperas, Green vitriol, FeO,SO_3+7HO. Is made by acting on iron by dilute HO,SO_3, evaporating and crystallising; $Fe+HO,SO_3=FeO,SO_3+H$. On the large scale, from the refuse HO,SO_3 of the refineries of petroleum, chloroform, etc., and old iron scraps; also by the oxidation of iron pyrites; the latter is too impure for medical use.

Prop.—When pure, is in bluish-green, transparent crystals of a styptic taste and acid reaction; soluble in 2 parts cold and ¾ boiling water; the crystals contain 7 eq. water of crystallisation, 6 of which they lose by a moderate heat (*Ferri Sulphas Exsiccata*); exposed to the air, becomes green and finally covered with a brownish efflorescence of subsulphate of sesquioxide; its solution is a pale green, becoming dark from the absorption of O. Is tonic and astringent; should be dried before making into pills. *Dose*, gr i to v. Mixed with an equal weight of lime, forms a cheap deodouriser for sinks, etc.

Liquor Ferri Tersulphatis, Solution of Ferric sulphate, $Fe_2O_3,3SO_3$.

Prep.—℞. *Acid. Sulphuric.* ℥ij gr lx, *Acid. Nitric.* ℥j gr ccclx, *Aquæ* Oss. *M.* Add *Ferri Sulphat. pulv.* ℥xii, one-fourth at a time, to the mixture, previously heated to the boiling-point, stirring after each addition until effervescence ceases, and heat until the liquid acquires a reddish colour and loses the odour of NO_4; when nearly cold, add *Aquæ* q. s. *ad* Ojss. The nitric acid is used to raise the ferrous oxide of the FeO,SO_3 to the ferric oxide, and an additional equivalent of HO,SO_3 is used for each of Fe_2O_3 formed to make a *normal* salt (243), $6(FeO,SO_3)+NO_5=3(Fe_2O_3,2SO_3)_{\rightarrow}+N\overset{\uparrow}{O}_2$; $Fe_2O_3,2SO_3+HO,SO_3=Fe_2O_3,3SO_3+HO$.

Prop.—A permanent clear reddish-brown liquid, s. g.

1·320, of an astringent, acrid taste, miscible without decomposition in all proportions with water and alcohol. Is rarely prescribed, being used chiefly in making other ferruginous preparations.

Liquor Ferri Subsulphatis, Monsel's solution, $2Fe_2O_3, 5SO_3$.

Prep.—℞. *Ferri Sulphat.* ℥xii, *Acid. Sulphuric.* ℥j gr xxx, *Acid. Nitric.* ℥j gr ccc, *Aquæ* q. s. The process is the same as that last described, making the quantity of solution at the end of the operation f℥xii.

The name *persulphate* of iron, commercially given to this preparation, is bad; persulphate means strictly a compound of persulphuric acid, a body unknown. If it is intended to mean sulphate of the peroxide, it is equally unfortunate. The use of the terms peroxide, persulphide, etc., for sesqui compounds should be banished from chemical nomenclature as indefinite. It is a *sub*sulphate, as it contains an excess of base.

Prop.—A ruby-red, syrupy solution, s. g. 1552, resembling that last described in general properties, but less acrid to the taste and less irritating. Is largely used as a styptic and astringent. On evaporation, yields deliquescent, readily soluble scales, but, like most sub-salts, does not crystallise.

Ferri et Ammoniæ Sulphas, Ammonio-ferric alum, $F_2O_3, 3SO_3+NH_4O,SO_3+24HO$.

Prep.—℞. *Liq. Ferri Tersulphat.* Oij, *Ammoniæ Sulphat.* ℥ivss. Heat the former to the boiling-point, add the latter with stirring; when dissolved, evaporate and crystallise. By using KO,SO_3 in proper proportion, a *potassio-ferric* alum, nearly identical in physical properties, is obtained.

Prop.—Resembles ordinary alum in most respects; the taste is sour, and it is rather more soluble. Is used in the same cases.

322. Phosphates.

Ferri Phosphas, $2FeO,HO,PO_5$, or $2FeO,Fe_2O_3PO_5$.

Prep.—Is made by double decomposition of *Sodæ Phosphas* (6 parts by weight) and *Ferri Sulphas* (5 parts by weight); $2NaO,HO,PO_5,+2(FeO,SO_3)=2FeO,HO,\underset{\downarrow}{PO_5}$ and $2(NaO,SO_{3\rightarrow})$. Should the FeO,SO_3 contain Fe_2O_3, it will combine in place of the basic water; the insoluble phosphate is filtered from the solution of the sulphate, washed and dried.

Prop.—A bright, slate-coloured powder, insoluble in water, but soluble in acids, which usually decompose it; it may be dissolved unchanged in *Metaphosphoric* acid, HO,PO_5, and in HCl.

Med. Effects.—Those of its constituents. *Dose*, gr v to x. Combined with phosphates of lime, soda potassa, and rendered soluble by HO,PO_5 or HCl, it constitutes the so-called chemical food.

Ferri Pyrophosphas.

Prep.—*Sodæ Phosphas*, $2NaO,HO,PO_5+24HO$, ℥viiss, is gradually heated to redness, by which it becomes pyrophosphate, $2NaO,PO_5$; it is then dissolved in *Aqua* Oiij, and *Liq. Ferri Tersulphat.* added as long as a precipitate falls; this is drained and washed; $3(2NaO,PO_5)+2(Fe_2O_3,3SO_3)=2Fe_2O_3,3\underset{\downarrow}{PO_5}+6(NaO,SO_{3\rightarrow})$. *Acid. Citric.* ℥ij is then saturated with *Aq. Ammoniæ;* the citrate of ammonia formed is mixed with the $2Fe_2O_3,3PO_5$, and the liquid evaporated to ℥xvi and poured on glass, when it dries into scales.

Prop.—Scales of an apple-green colour and acid saline taste, freely soluble in water. Contains 48 p. c. of pyrophosphate of iron, which is held in solution by the citrate of ammonia. Dose, gr ij to v, in water or syrup.

233. Lactate, *Ferri Lactas*, $FeO,C_6H_5O_5+3HO$.

Prep.—By the action of dilute lactic acid on iron filings. $Fe+HO,C_6H_5O_5=FeO,C_6H_5O_5+H$.

Prop.—Greenish-white crystalline grains, of a sweetish taste, soluble in 48 parts cold and 12 boiling water. Dose, gr x to xx.

324. **Tartrates.**

Ferri et Potassæ Tartras, $KO,Fe_2O_3,C_8H_4O_{10}+HO$.

Prep.—By heating cream of tartar, mixed with water, to 140°, and adding ferric hydrate as long as it will dissolve. $KO,HO,C_8H_4O_{10}+Fe_2O_3,3HO=KO,Fe_2O_3,C_8H_4O_{10}+4HO$. The salt, not being *normal* (243), does not crystallise. The solution is evaporated to the consistence of syrup, and spread upon panes of glass to dry.

Prop.—Ruby-red, transparent scales, of a sweetish taste, soluble in 4 parts water. Contains about 30 p. c. of Fe_2O_3. Is slightly laxative. Dose, gr x to xxx.

Ferri et Ammoniæ Tartras, $NH_4O,Fe_2O_3,C_8H_4O_{10}+4\,?\,HO$.

Prep.—(1) Saturate ℥vi *Acid. Tart.* dissolved in Oij *Aquæ destillat.* with *Ammoniæ Carb.* q. s.; then add ℥vi more of *Acid. Tart.* (2) Saturate the resulting bitartrate of ammonia with ferric hydrate, and proceed as in the last preparation. The reactions involved and the properties and dose are similar.

325. **Citrates,** *Liquor Ferri Citratis.*

Prep.—By saturating a solution of citric acid at 150° with $Fe_2O_3,3HO$. ℥vʒvi of citric acid yield a pint of solution.

Prop.—A deep reddish, permanent solution, of a slight ferruginous taste; contains ℥ss of $Fe_2O_3,C_{12}H_5O_{11}$ to the f℥j. By evaporation the solution as directed for the tartrates, there is obtained the *Ferri Citras* in scales resembling in general properties and dose those preparations.

Ferri et Ammoniæ Citras, $NH_4O,Fe_2O_3,C_{12}H_5O_{11}+2HO$. ℞. *Liq. Ferri Citrat.* Oj, *Aquæ Ammoniæ* f℥vj. M. The solution is evaporated at a temperature not exceeding 150° and treated as the citrate. It is more soluble than the latter, but otherwise resembles it; it contains 24·5 p. c. of Fe_2O_3.

Ferri et Quiniæ Citras, $Fe_2O_3,\overline{C_{40}H_{24}N_2O_4},C_{12}H_5O_{11}+HO$?

Prep.—By saturating *Liq. Ferri Citrat.* with *Quinia* obtained by precipitating the sulphate of quinia by ammonia in slight excess. The temperature of the solution during the operation should be 120°. It is evaporated and obtained in scales, of reddish-brown colour, bitter and ferruginous taste, slowly soluble in cold water. Dose, gr v to x.

Other preparations of iron, as the acetate, tannate, valerianate, prototartrate, perchlorate, citrate of iron with strychnia, magnesia, and zinc; double phosphates of iron and ammonia, iron and lime, etc., etc., have been made and used. Fortunately they are not officinal as the list is already crowded with compounds differing but little in physical and medical properties.

CHROMIUM, $Cr=26$.

326. *Sources.*—Chrome iron ore, FeO,Cr_2O_3, and, rarely, native chromate of lead, PbO,CrO_3. The former by fusion with nitre gives the chromate of potassa, KO,CrO_3, from which the other compounds are derived.

Prep. and Prop.—By reduction of the oxide by C. Is a hard, grayish-white metal; s. g. 5·9; difficult of fusion, and does not readily oxidise.

Chem. Rel.—Resembles closely manganese and iron; with O forms *Protoxide*, CrO; *Sesquioxide*, Cr_2O_3, bases; *Chromic Acid*, CrO_3, and *Perchromic Acid*, Cr_2O_7.

Acidum Chromicum, CrO_3, is prepared by the action of strong HO,SO_3 upon bichromate of potassa, $KO,2CrO_3$. It crystallises in brilliant red prisms; very deliquescent and soluble in water. It has been used in medicine as an escharotic. It rapidly dissolves organic matter, except gun-cotton and paraffine, and is a powerful oxidising agent, becoming reduced to Cr_2O_3. The chromates are remarkable for their brilliant colours and are used as pigments, especially those of baryta, lead, and antimony.

Potassæ Bichromas, $KO,2CrO_3$, possesses the properties of CrO_3, but in a milder degree. It is used as an escharotic and as an oxidising agent. Internally, in large doses, is an irritant poison. Antidotes: mild alkalies, demulcents. Has been used in small doses (gr $\frac{1}{5}$, gradually increased) in secondary syphilis. None of the other preparations of chromium are used in medicine. Workmen engaged in manufactures where it is used are liable to painful ulcerations.

NICKEL and COBALT.

327. Two metals, isomorphous with iron, zinc, and copper. They occur in nature as arsenides and generally associated. They are not employed in medicine.

Nickel, $Ni = 29{\cdot}5$.—A white metal, s. g. 8 to 8·8; difficult of fusion, is magnetic; occurs in meteoric stones. Its protoxide, NiO, forms salts of a delicate green colour. Nickel is chiefly employed in the manufacture of German silver, which contains 100 parts copper, 60 of zinc, and 40 of nickel.

Cobalt, $Co = 29{\cdot}5$.—Resembles nickel in properties and chemical relations. Its protoxide, CoO, forms pink salts, but is precipitated by alkalies as a blue hydrate. The chloride, $CoCl$, is used in dilute solution as a sympathetic ink, being invisible until heated, when it becomes blue, and again fades, if not too highly heated, on cooling. Cobalt is employed to give a blue colour to glass and artificial gems; also in blowpipe analysis.

COPPER, $Cu = 31{\cdot}7$.

328. *Sources.*—Occurs native, and as oxide, carbonate (malachite), and sulphide (copper pyrites, Fe_2S_3CuS).

Prop.—A brilliant, sonorous, very malleable and ductile metal, of a characteristic colour, slightly nauseous taste, and disagreeable odour when rubbed; s. g. 8·89; fuses at 1996°; is but little affected in dry air; in moist air, especially in the presence of acids, becomes coated with a green carbonate. At a red heat it becomes covered with a black scale of CuO.

Chem. Rel.—Forms three oxides: Suboxide Cu_2O, Protoxide CuO, and an undetermined higher oxide, which is acid. The protoxide is of a black colour, its salts are isomorphous with those of zinc and of a rich blue or green colour. Those of Cu_2O are colourless.

The *alloys* of copper are numerous and valuable. Brass contains copper with 28 to 34 p. c. of zinc; muntz metal, 60 copper to 40 zinc; gun metal, 90 copper to 10 tin; aluminium bronze, 90 copper, 10 aluminium; Austrian gun metal, remarkable for tenacity, copper 55·04 p. c., zinc 42·36, tin 8·3, iron 1·77. Babbit's antifriction metal, 24 each copper and tin, and 8 of antimony.

Tests.—Ammonia throws down a blue precipitate, soluble in excess; Ferrocyanide of potassium a brown, and Hydrosulphuric acid a black precipitate.

329. **Sulphate,** *Cupri Sulphas,* CuO,SO_3+5HO; Blue vitriol.

Prep.—May be obtained by boiling Cu in HO,SO_3; SO_2 is given off; $Cu+2(HO,SO_3)=CuO,SO_3+SO_2+2HO$. On the large scale, by roasting the native sulphide, or by dissolving copper scales (CuO) in HO,SO_3.

Prop.—Rich, deep blue, oblique rhomboidal (5th system) crystals, of a nauseous, styptic taste, soluble in 4 parts cold and 2 of boiling water. When heated, it undergoes aqueous fusion, then dries and becomes white; at a high temperature, is decomposed.

Med. Effects.—In small doses, tonic, antispasmodic, and astringent; in large doses, emetic; externally, escharotic, and in solution astringent.

In large doses, ℥ss and more, an irritant poison, but not likely to be taken, on account of its taste. Antidotes: magnesia, albumen; the same may be said of all the salts of copper. When copper vessels are used in preparing food, or when workmen are exposed to it, slow poisoning may also take place, giving rise to cramps, diarrhœa, and dysentery.

Incompat.—Those of the soluble sulphates; metallic iron and zinc; the alkalies and their carbonates.

330. *Cupri Subacetas*, Verdigris; impure Subacetate of copper.

Prep.—Is made by stratifying sheets of copper and refuse of grapes; the alcohol in the husks becomes acetic acid, and unites with oxide of copper formed upon the plate. Its composition is variable; contains $3CuO,2C_4H_3O_3+6HO$, and $3CuO,C_4H_3O_3+3HO$.

Prop.—Pale, greenish or blue masses composed of silky needles; soluble in ammonia, insoluble in alcohol. and decomposed by water into neutral acetate, $CuO,C_4H_3O_3$, and trisacetate, $3CuO,C_4H_3O_3$.

Med. Effects.—Used only externally as an escharotic and astringent; internally, like the other salts of copper, is poisonous.

331. *Cuprum Ammoniatum*, Ammoniated copper.

Prep.—Is made by rubbing (℥ss) *Cupri Sulphat.* with gr ccclx (℥vi) *Ammon. Carb.* until effervescence ceases.

Rem.—The composition of this compound is not understood; probably a *cupro-sulphate of ammonia*, $NH_4O,SO_3 + NH_4O,CuO + HO$, in which the oxide of copper acts the part of an acid.

Prop.—A beautiful, deep azure-blue salt, with a strong ammoniacal odour, and styptic, metallic taste; is freely soluble in water; rapidly decomposes on exposure to the air.

Med. Effects.—Tonic and antispasmodic.

Incompat.—All acids; the alkalies and earths generally, and their carbonates.

332. Of the compounds of copper not used in medicine the following are the most important. The chloride, $CuCl + 2HO$, is soluble in alcohol, to the flame of which it communicates a green colour. The oxychloride, $3(CuO,HO) + CuCl + HO$, occurs native as *atacamite*, and is known in commerce as *Brunswick green*. The carbonate occurs native as *malachite*, $CuO,HO + CuO,CO_2$, and *azurite*, $CuO,HO + 2(CuO,CO_2)$; in commerce the same compounds, artificially prepared, are known as green and blue *verditer*.

ZINC, Zn=32·5.

SYLLABUS.

METAL, *Zincum*.

OXIDE, ZnO; *Zinci Oxidum*, Zinc white, Flowers of zinc; *Ung. Zinci Oxidi*.

CHLORIDES, $ZnCl$; *Zinci Chloridum*, Butter of Zinc; Burnett's disinfecting solution; Oxychloride, $ZnCl,3ZnO + 2HO$.

CARBONATE; *Zinci Carbonas Præcipitata*, $8ZnO,3CO_2 + 6HO$, *Ceratum Zinci Carbonatis*.

SULPHATE, $ZnO,SO_3 + 7HO$; *Zinci Sulphas*, White Vitriol.

ACETATE, $ZnO,C_4H_3O_3+2HO$; *Zinci Acetas.*

VALERIANATE, $ZnO,C_{10}H_9O_3$; *Zinci Valerianas.*

333. *Sources.* — The native sulphide, ZnS (blende); carbonate, ZnO,CO_2 (calamine); and silicate, ZnO,SiO_3+HO (electric calamine). It is obtained by roasting and reduction.

Prop.—A bluish-white, rather hard metal; s. g. 6·8; of a peculiar odour when rubbed. Commercial zinc is somewhat brittle; between 212° and 300° it becomes malleable, above 400° again brittle, and may be beaten into powder. Zinc may be conveniently *granulated* by holding above a pan of water a common broom thoroughly wetted, and pouring the molten metal over it. It melts at 770°, and is volatile at a bright-red heat; if volatilised in the presence of air, it burns with a bright bluish-white flame and evolution of a cloud of ZnO (philosopher's wool). Exposed to air, it tarnishes superficially, and the coating of oxide formed protects in a measure the metal within; acids corrode it rapidly.

Chem. Rel.—Forms one oxide, ZnO, the salts of which are isomorphous with those of magnesia. Its salts are colourless and generally soluble. *Test.* NH_4S,HS throws down a characteristic *white* sulphide of zinc, HS does so only in neutral solutions.

Med. Effects.—The salts of zinc are tonic, antispasmodic, and astringent.

334. **Oxide**, ZnO, *Zinci Oxidum.*

Prep.—On the large scale by burning zinc; a purer form is obtained by exposing the precipitated carbonate to a low red heat until HO and CO_2 are expelled; this is the official process.

Prop.—A tasteless, inodorous, white powder, insoluble in menstrua except the acids and caustic alkalies. It becomes yellow when heated, but white again on cooling.

It is the *zinc white* of commerce used as a substitute for white lead, as being less liable to produce symptoms of metallic poisoning. Dose, gr ij to x. The *Unguentum Zinci oxidi* is made by rubbing up ℥j *Zinci Oxidi* with ℥vi *Adipis.* Is used externally as a mild astringent.

335. **Chloride,** $ZnCl$; *Zinci Chloridum,* Butter of Zinc.

Prep.—By direct combination of its elements, or by the action of HCl on $Zn = ZnCl + H$. In the officinal process ℥iiss of zinc is dissolved in *Acid. muriat.* q. s., the solution strained, *Acid. nitric.* gr lx added, and the whole evaporated to dryness. The dry mass is dissolved in f℥v *Aquæ,* and gr lx *Cretæ Præparatæ* added, the whole allowed to stand 24 hours. It is then filtered, evaporated to dryness, fused, poured upon a slab, and when solid broken into fragments which must be kept in a well-stopped bottle. The nitric acid and chalk are to get rid of iron, the former produces a ferric salt which is mostly decomposed by heat, the chalk neutralises any excess of acid and precipitates a soluble salt of iron as carbonate.

Prop.—A white deliquescent salt, wholly and freely soluble in water and alcohol. Burnett's disinfecting solution contains gr cc to ℥i, and has a s. g. of 2. It acts by absorbing HS and by preventing decay by coagulating albuminoid matters. $ZnCl$ forms a series of double salts of which the double chloride of zinc and ammonium, $ZnCl, NH_4Cl$, is used in soldering to dissolve metallic oxides. *Zinci Chloridum* is used externally as an escharotic, or in dilute solution as an astringent. In large doses is an irritant poison; *antidotes,* soap, the alkaline carbonates. The *oxychloride,* $ZnCl, 3ZnO + 2HO$, is made by mixing a concentrated solution of $ZnCl$ with ZnO, recently prepared by burning zinc. It hardens rapidly, is used as a filling for decayed teeth, and as a cement generally.

336. **Carbonate**, *Zinci Carbonas Præcipitata.*

Prep.—By mixing equal weights of *Zinci Sulph.* and *Sodæ Carb.* dissolved in water, washing and drying the precipitate.

Prop.—A smooth, white powder, which should be wholly dissolved with effervescence in dilute HO,SO_3. Its composition is not constant, is a mixture of the carbonate and hydrate of the oxide, or a carbonate containing an excess of oxide, $8ZnO,3CO_2+6HO$, or $(ZnO,CO_2+HO)+2(ZnO,HO)$. Is used as a substitute for the native carbonate *Calamine*, which is generally impure. Is used externally only. *Ceratum Zinci Carbonatis*, a substitute for the old *Ceratum Calaminæ*, Turner's cerate, is made by mixing ℥ij *Zinc. Carb. Præcip.* with ℥x *Ung. Adipis.* Resembles the *Ung. Zinci Oxidi.* The neutral carbonate ZnO,CO_2 occurs native as *Calamine.*

337. **Sulphate**; *Zinci Sulphas*, White vitriol, ZnO,SO_3+7HO.

Prep.—By the action of dilute HO,SO_3 upon $Zn=ZnO,SO_3+H$.

Prop.—Colourless, transparent, right rhombic crystals (3d system) much resembling epsom salt; has a slight acid reaction, is soluble in 2½ parts cold and less than its weight of boiling water; taste styptic, astringent; when heated, it undergoes aqueous fusion, becomes anhydrous, and finally loses its acid.

Med. Effects.—Small doses, gr j to ij, tonic, astringent, antispasmodic; in large, gr xxx, emetic; in overdose, an irritant poison, rarely fatal, from its producing vomiting; its effects are combated by mucilage and albumen. Externally applied, is astringent and escharotic.

Incompat.—The alkalies and alkaline earths, their carbonates; lead salts; vegetable astringents.

338. **Acetate,** $ZnO,C_4H_3O_3+2HO$; *Zinci Acetas.*

Prep.—Plumb. Acetat. ℥xii is dissolved in Oijj *Aq. Destillat.* To this is added ℥ix *Zinci* (granulated) and the whole shaken occasionally until the liquid does not yield a yellow precipitate upon the addition of KI (absence of Pb). It is then filtered slightly, acidulated with acetic acid, and crystallised; $PbO,C_4H_3O_3+Zn=ZnO,C_4H_3O_3^{\rightarrow}+\underset{\downarrow}{Pb}$. Should the crystals be coloured, re-dissolve and add *Zinci carb. præcip.* until a portion evaporated yields colourless crystals.

The use of the carbonate is to remove any iron. The acetate may be rapidly and conveniently prepared by saturating acetic acid, $HO,C_4H_3O_3$, with the precipitated carbonate. It is often made extemporaneously by mixing in the same prescription solutions of ZnO,SO_3+7HO and $PbO,C_4H_3O_3+3HO$. If equal weights are employed, the latter salt will be slightly in excess. The presence of insoluble sulphate of lead in this case must be borne in mind; it may be useful in gonorrhœa, etc., but highly improper in a collyrium. $ZnO,SO_3+PbO,C_4H_3O_3=ZnO,C_4H_3O_3{\rightarrow}+\underset{\downarrow}{PbO,SO_3}$.

Prop.—In colourless, efflorescent, hexagonal (6th system) plates, very soluble in water, somewhat so in alcohol. Is only employed externally; is a mild astringent. Is incompatible with the mineral acids, the alkalies, earths, their carbonates, and the vegetable astringents.

339. **Valerianate;** *Zinci Valerianas,* $ZnO,C_{10}H_9O_3$.

Prep.—By double decomposition of *Sodæ Valerianat.* ℥iiss and *Zinci Sulphat.* ℥ij gr ccccxx, each dissolved in f℥xx *Aquæ Destillat.* and heated to the boiling-point before admixture. $ZnO,SO_3+NaO,C_{10}H_9O_3=ZnO,C_{10}H_9O_3^{\rightarrow}+NaO,SO_3{\rightarrow}$. By evaporation, the less soluble *Zinci valerianas* crystallises out first, and the evaporation may be continued until the liquid is but $\frac{1}{10}$ of the original bulk The crystals are washed with cold, distilled water, to remove any NaO,SO_3.

Prop.—In anhydrous, white, pearly scales, soluble in 160 parts cold water and 60 of alcohol of 0·833, having a faint odour of valerianic acid, a metallic, styptic taste, and a slightly acid reaction. Used as an antispasmodic. *Dose,* gr i to ij in pill. *Incompatibles,* those of the acetates.

CADMIUM, $Cd=56$.

340. *Sources.*—Cadmium occurs associated with zinc in its ores, and being more volatile comes over with the first portions of the vapour of that metal when it is distilled. The two are dissolved in excess of HCl. HS is passed through the solution, which precipitates only the Cd as an orange-yellow sulphide, CdS. From this the carbonate is readily obtained, and from the latter the metal.

Prop.—Much resembles tin, but is more volatile, tenacious, and heavier; when bent or twisted, has a *cry* like tin; s. g. 8·7; melts at 440°, volatilises below a red heat, does not oxidise readily at ordinary temperatures. Forms a protoxide, CdO, which is a base forming colourless salts. The sulphide is used in pyrotechny, and the iodide (made by mixing I and Cd filings moistened) as a substitute for PbI. The metal is officinal as *Cadmium.*—*Test.* NH_4HS gives a yellow precipitate of CdS, insoluble in excess or in KO,HO or NH_4O,HO, and thus distinguished from the sulphide of arsenic, As,S_3.

341. **Sulphate,** *Cadmii Sulphas,* CdO,SO_3+4HO.

Prep.—℥j *Cadmii* is acted upon by f℥ij *Acid. Nitric.* diluted with an equal bulk of distilled water, $Cd_3+4(HO,NO_5)=3(CdO,NO_5)+4HO+NO_2$. To the nitrate thus formed is added ℥iij *Sodæ Carb.* dissolved in f℥vi *Aquæ Destillat.* $CdO,NO_5+NaO,CO_2=\underset{\downarrow}{CdO,CO_2}+NaO,NO_{5}\rightarrow$. The precipitated carbonate is washed and treated with

Acid. Sulph. gr ccccxx, diluted with f℥iv *Aquæ Destillat.* $CdO,CO_2+HO,SO_3=CdO,SO_3+HO+CO_2$. This apparently circuitous process is rendered necessary by the fact that HO,SO_3 does not readily act on Cd, but rapidly decomposes its carbonate.

Prop.—In colourless, efflorescent, oblique rhomboidal prisms (5th system), freely soluble in water. Used externally as a lotion, gr ss to ij to ℥j *Aquæ;* or ointment, gr ij to ℥j, in ophthalmia and corneal specks. Is esteemed alterative, but is rarely used internally.

BISMUTH, Bi=210.

342. *Sources.*—Occurs native and as oxide.

Prop.—A brittle, crystalline, (rhombohedral, 6th system) metal, having a white colour with a reddish tinge, s. g. 9·8, fuses at 507 and burns at a higher temperature, giving rise to yellow fumes, which on cooling become white BiO_3.

Chem. Rel.—Forms BiO_3, a feeble base, BiO_5 Bismuthic Acid, and BiO_4, which is probably a compound oxide, $2BiO_4 = BiO_3,BiO_5$. The chloride $BiCl_3$ may be made by direct combination, or by dissolving BiO_3 in $3HCl=BiCl_3+3HO$. It is a deliquescent solid (butter of bismuth) decomposed by water into *oxychloride* and HCl; a small quantity remains undecomposed. $3BiCl_3 + 6HO = \underset{\downarrow}{\overline{BiCl_3, 2BiO_3}} + 6HCl_{\rightarrow}$. This precipitate, as well as the subnitrate, is sold as *pearl powder* and *pearl white*, and used as a cosmetic; they both blacken by HS. The other important salts will be considered under the preparations.

Alloys.—Bismuth and its alloys expand on cooling, and hence are adapted for taking casts. Fusible metal melts at 200°, and contains 2 parts of Bi, one of Pb, and one of Sn; by the addition of Cd and Hg, the fusing-point may be reduced still lower. *Test.* The salts of bismuth are decomposed by an excess of water, and the precipitates formed blackened by HS.

343. **Nitrates**; *Bismuthi Subnitras*, BiO_3,NO_5.

Prep.—When Bi in powder is acted upon by nitric acid, it dissolves with evolution of NO_4. $Bi+4(HO,NO_5)=BiO_3,3NO_5+4HO+NO_2$. When crystallised, this normal nitrate of bismuth contains 9 eq. of water of crystallisation. On the addition of water a white precipitate falls, the *magistery of bismuth, pearl powder*, etc. In this case the water acts as a base and displaces a portion of BiO_3, leaving a precipitated subnitrate and an acid supernitrate, $4(BiO_3,3NO_5)=3(BiO_3,NO_5)\downarrow+BiO_3,9NO_5\rightarrow$. The composition of the precipitate is not constant. The commercial subnitrate frequently contains arsenic, and the new process, U. S. P., is designed to avoid this impurity. ℥ij *Bismuthi* are submitted to the action of ℥iv *Acid. Nitric.* diluted with ℥iv *Aquæ Destillatæ* for 24 hours. The resulting $BiO_3,3NO_5$ is diluted with f℥x *Aq. Destillat.*, which is not enough to cause decomposition, but merely a slight turbidness. The solution is filtered, and to it is added a solution of *Sodæ Carb.* ℥x dissolved in f℥xx *Aquæ Destillat.* previously filtered, and the whole stirred; the precipitate of carbonate of bismuth is thoroughly washed, and to it is added ℥vi *Acid. Nitric.* and the whole heated nearly to the boiling-point, re-forming the nitrate; when cold, *Aq. Destillat.* is added until it begins to produce milkiness. It is then allowed to stand for 24 hours, and is filtered; Oiv *Aquæ Dest.* is added and then f℥vj *Aquæ Ammoniæ* with constant stirring. The precipitate is then washed and dried. The excess of NaO,CO_2 is used to retain any As, as arseniate of soda; if any arseniate of bismuth be formed, it will be precipitated upon the addition of the small quantity of water to the nitrate. The use of NH_4O,HO is to more completely precipitate the subnitrate.

Prop.—A heavy, white powder, of a feebly acid taste and reaction, insoluble in water even when carbonated. It should give no trace of As in Marsh's apparatus. See ARSENIC.

Med. Effects.—Used in chronic affections of the stomach and bowels, as gastralgia and diarrhœa; externally, as a desiccating application to burns and ulcers, and suspended in water as an injection in gonorrhœa and leucorrhœa. Dose, gr v to xxx.

344. **Carbonate**; *Bismuthi Subcarbonas*, BiO_3,CO_2.

Prep.—By preparing a normal nitrate with the proportions and precautions indicated in the last article, precipitating with excess of ammonia, re-dissolving, as before, in dilute HO,NO_5, and precipitating with carbonate of soda in excess.

Prop.—A white or yellowish-white, heavy powder, insoluble in water or carbonic acid water, soluble in nitric acid with effervescence. Should give no indications of As with Marsh's test. Used in the same cases and doses as the subnitrate.

LEAD, Pb=103·5.

SYLLABUS.

OXIDE, PbO, *Plumbi Oxidum*, Litharge, *Emplastram Plumbi.*

IODIDE, PbI, *Plumbi Iodidum.*

CARBONATE, *Plumbi Carbonas*, White lead, PbO,CO_2, or $2(PbO,CO_2)+PbO,HO$; *Unguentum Plumbi Carbonatis.*

NITRATE, PbO,NO_5, *Plumbi Nitras.* Ledoyen's solution contains gr lx to f℥j *Aquæ.*

ACETATES: *Plumbi Acetas*, $PbO,C_4H_3O_3+3HO$; *Liquor Plumbi Subacetatis*, Goulard's extract, $3PbO,C_4H_3O_3$; *Liq.*

Plumb. Subacetat. dilutus f℥iij to Oj *Aquæ*, Lead water: *Ceratum Plumbi Subacetatis*, Goulard's cerate.

345. *Sources.*—The native sulphide, PbS (Galena), and phosphate Pyromorphite, $3PbO,PO_5+PbCl$, rarely the binoxide, PbO_2, carbonate, PbO,CO_2, sulphate, PbO,SO_3. Obtained by roasting and reduction; the sulphide frequently contains an important percentage of silver.

Prop.—A soft, bluish-white, malleable, imperfectly ductile metal, s. g. 11·45; melts at 620°, and becomes covered with a coating of oxide, mostly protoxide PbO, is brittle just below its melting point; soon tarnishes in moist air, from the formation of suboxide Pb_2O? In pure water, lead becomes coated with scales of oxide, which dissolve and are again precipitated as insoluble oxycarbonate (Brande and Taylor). The presence of alkalies, the nitrates and chlorides, as well as of CO_2, increases the action of water upon lead; it is diminished by carbonates, sulphates, and phosphates, especially of lime, which form a coating on the inside of the pipe or vessel protecting it; $\frac{1}{5000}$ part of CaO,SO_3 will produce this effect. As all ordinary river-water contains these salts, lead cannot generally be detected in hydrant water, but may be found in *mineral water*, and in situations where the solder of the lead may be acted upon by acid or alkaline waters. It is removed by filtration through animal charcoal, or agitation with enough powdered chalk to make a liquid of a creamy consistence.

Chem. Rel.—Forms Pb_2O, suboxide; PbO, Pb_2O_3, and PbO_2, puce or brown oxide—plumbic acid; also *minium* or red lead, an intermediate oxide Pb_3O_4, or $2PbO,PbO_2$. PbO is obtained by direct oxidation, by precipitation as a hydrate, or by heating its carbonate. It is a powerful base resembling in some respects the alkalies, in which it is soluble; it is also slightly soluble in water; it readily unites with silica and the earths and metallic oxides, forming fusible, vitreous bodies. It enters into the composition of flint glass. By exposing PbO to a temperature between 570° and 580°, it absorbs O, and becomes of a brilliant red colour, forming minium or red lead, Pb_3O_4. By the action of acids, this oxide yields proto-compounds, and PbO_2 is left; the latter is a brown powder, readily giving up its O, by action of heat or acids, in the form of ozone. The chloride PbCl is soluble in 135 parts cold and 33 of boiling water, and insoluble in alcohol. Other compounds will be considered under the preparations.

Tests. — HS and NH_4S,HS give a black precipitate; KI and KO,CrO_3, a brilliant yellow; HO,SO_3, or the soluble sulphates, a white.

Incompatibles. — The soluble chlorides, iodides, sulphites; the sulphates, the alkalies and their carbonates; the vegetable astringents.

Med. Effects. — The salts of lead are sedative and astringent. In large doses, poisonous; *antidote*, the soluble sulphates or dilute sulphuric acid. Persons engaged in manufactures of lead are liable to lead colic and palsy. The best mode of prevention is frequent washing of the hands and body, and the use of a sulphuric acid lemonade.

347. **Oxide**, *Plumbi Oxidum*, Litharge, Massicot, PbO.

Prep. — On the large scale, by exposing melted lead to a current of air.

Prop. — Small, brilliant, red or yellow vitrified scales, fusing at a red heat. Slightly soluble in water; *saponifies* with oils. Absorbs CO_2 by exposure to the air. Is readily dissolved in dilute HO,NO_5. Is largely employed in the arts, in painting, etc. Is not used as medicine, but enters into other officinal compounds, as *Emp. Plumbi*, *lead plaster;* which is made by boiling together Litharge ℥xxx, Olive Oil ℥lvi, and Water q. s.

348. **Iodide,** *Plumbi Iodidum*, PbI.

Prep.—By double decomposition of *Plumbi Nitrat.* ℥iv dissolved in Oiss *Aquæ Destillat.*, and *Potass. Iodid.* ℥iv in *Aquæ Destillat.* Oss. The precipitate is washed and dried as usual; $PbO,NO_5+KI=\underset{\downarrow}{PbI}+KO,NO_{5\rightarrow}$.

Prop.—A bright yellow, heavy, inodorous powder, fusible and volatilised by heat, soluble in 1235 parts cold and 194 of boiling water. The boiling solution on cooling deposits the salt in brilliant golden-yellow scales. Is used externally only, in ointment.

349. **Nitrate,** *Plumbi Nitras*, PbO,NO_5.

Prep.—By dissolving Litharge in dilute HO,NO_5; when crystallised, is in the form of white, nearly opaque, regular octohedra (1st system); soluble in water and alcohol, and having a sweetish, astringent taste.

Uses.—Is never used internally; rarely externally. It is employed as a deodoriser. *Ledoyan's Disinfecting Solution* contains gr lx to ℥j water. It acts by absorbing HS, giving rise to PbS.

350. **Carbonate,** *Plumbi Carbonas*, White lead, PbO,CO_2, or $2(PbO,CO_2)+PbO,HO$.

Prep.—On the large scale, by exposing metallic lead to the action of vapour of vinegar in a hot-bed. A subacetate, $3PbO,C_4H_3O_3$, is formed, which becomes carbonate by absorption of CO_2, liberating the acetic acid, which acts on a fresh portion of metallic lead.

Prop.—Fine, white, heavy, opaque, inodorous, nearly tasteless, insoluble powder. Dissolves freely in acids, with evolution of CO_2.

Med. Effects.—Is highly poisonous; cases of acute poisoning are rare. The alkaline sulphates, generally employed as antidotes, are of little use; dilute HO,SO_3, or *Acid. Sulph. Arom.*, with emetics and purgatives, should be used. It is the salt which most commonly causes le colic and palsy. It is used externally only, as a sedative astringent.

Unguentum Plumbi Carbonatis. Prep.—By rubbing up ℥ij *Plumb. Carb.* and *Ung. Simp.* ℔j; first softening the latter by heat

351. **Acetates.**

Plumbi Acetas, Sugar of Lead, $PbO,C_4H_3O_3+3HO$.

Prep.—Is prepared, on the large scale, by the action of acetic acid on lead plates frequently exposed to the air, or by dissolving litharge in the acid.

Prop.—White crystals (4th system), of a sweetish, astringent taste, and slightly efflorescent. Soluble in 1½ parts cold water; the solution is turbid, on account of the formation of carbonate, from the presence of carbonic acid in ordinary water. Is sedative and astringent. Dose, gr v. In overdose, a poison; antidote, the soluble sulphates.

Liquor Plumbi Subacetatis, Goulard's extract.

Prep.—Is made by boiling together, *Plumbi Acetat.* ℥xvj, *Plumb. Oxid. Semivit. pulv. subtil.* ℥ixss, and *Aq. Destill.* Oiv, for half an hour; adding water to keep up the quantity, and filtering. The s. g. of the solution is 1·267. In this case an additional quantity of PbO is given to the acetate, forming $3PbO,\overline{A}$ (trisacetate), or $2PbO,\overline{A}$ (diacetate). The liquid has a sweetish, astringent taste, and absorbs CO_2 with great avidity, becoming turbid; hence should be kept in well-stopped bottles; it forms a dense white precipitate with a solution of gum.

Med. Effects.—Used only externally; is more poisonous than the acetate. Antidotes the same.

Liquor Plumbi Subacetatis Dilutus, Lead Water.

Prep.—Is made by diluting the last preparation, fʒiij to Oj. It is turbid when first made, but if kept well-stopped, becomes clear, by the subsidence of the carbonate.

Ceratum Plumbi Subacetatis, Goulard's cerate.

Prep.—℥iv *Ceræ Albæ* is melted with ℥vii *Ol. Olivæ;* the mixture is then removed from its fire, and when it begins to thicken, f℥iiss *Liq. Plumb. Subacetat.* is stirred in with a wooden spatula until it becomes cool; to this is added gr xxx *Camphoræ* dissolved in ℥j *Ol. Olivæ.* It does not keep well.

TIN, Sn=59.

352. *Sources.* — The native oxide SnO_2; is obtained by reduction.

Prop.—A silvery white, malleable, slightly ductile metal, fusible at 442°, volatile at a white heat, s. g. 7·28. It emits a peculiar odour when heated or rubbed; when bent, crackles, the *cry* of tin; does not oxidise at ordinary temperatures, but when melted becomes first SnO, and finally SnO_2. Burns in the flame of the compound blowpipe. Tin foil is usually adulterated largely with lead. Tin plate is iron coated with tin, which, being electro-negative to the former, causes rapid oxidation when the surface is abraded (165). Tin is not readily acted upon by chemical agents.

Chem. Rel.—Forms three oxides: SnO, a feeble base; Sn_2O_3, unimportant; and SnO_2, Stannic acid. SnO is formed by direct oxidation (*putty powder*), or as a hydrate by precipitation by the alkalies or their carbonates from the chloride SnCl; the latter is soluble in dilute acids and in caustic potassa or soda. SnO_2, made by precipitation from $SnCl_2$, by alkalies or their carbonates, forms salts with the alkalies of which the stannate of soda, NaO,SnO_2+4HO, is used as a mordant (299). It is also soluble in acids. The stannic acid obtained by the action of dilute HO,NO_5 upon tin differs in some important respects from stannic acid obtained by precipitation; it has been termed *metastannic* acid; its salts are not crystallisable. Tin forms SnS, Sn_2S_3, and SnS_2; the latter is known as *aurum musivum*, or mosaic gold; it is only soluble in *Aqua Regia*, and has a golden lustre; s. g. 4·5. Is used as a bronzing powder. The protochloride SnCl may be made by the action of HCl upon Sn; it easily decomposes; is a powerful reducing agent, used to remove ink spots, as a mordant, and as a test for HgCl, from which it precipitates Hg in a finely divided state. $SnCl_2$, made by the action of *Aqua Regia* on tin, is a colourless, fuming liquid, used as a mordant. *Tests.* Corrosive sublimate, HgCl, gives with the protochloride a gray precipitate of metallic mercury; chloride of gold, $AuCl_3$, a rich purple; the bichloride is precipitated of a dingy yellow colour by NH_4S,HS, soluble in excess. The oxysalts of tin are rarely met with.

Med. Effects.—Powdered tin is used as an anthelmintic, and was formerly officinal as *Pulvis Stanni.* The chlorides are poisonous; antidotes, albumen, milk, or flour paste.

ARSENIC, As=75.

353. *Sources.*—This element is widely diffused, occurring generally combined with the sulphides of the metals, as those of iron, copper, nickel, cobalt, and zinc; also as the native sulphides, *Realgar*, AsS_2, and *Orpiment*, AsS_3; it is present in many natural waters. When its ores are heated, arsenious acid, AsO_3, is formed, from which the metal is readily obtained by reduction.

Prop.—A steel-gray, brittle, crystalline rhombohedral (6th system) metal, s. g. 5·75; has a brilliant lustre when freshly broken, but speedily tarnishes and in moist air falls to a brownish powder (suboxide?); it volatilises at 400° without fusion, unless under pressure; the density of its vapour is 10390; if air be present, white fumes of AsO_3

are formed during its volatilisation, and a garlicky odour is exhaled.

Chem. Rel.—Is more electro-negative than H, and forms a member of a natural group with N, P, and Sb; does not form a base with any of the amphigens, and is only placed among the metals on account of its metallic lustre, insolubility, and power of conducting electricity. With O it forms an undetermined suboxide, arsenious acid, AsO_3, and arsenic acid, AsO_5. *Arsenic acid* is made by the action of HO,NO_5 on AsO_3; it is freely soluble in water; of a sharp, acid taste, highly poisonous, and gives a brick-red precipitate with ammonio-nitrate of silver. Like PO_5, it is tribasic ($2CuO,HO,AsO_5$, arseniate of copper), but no compounds corresponding to the pyro and meta-phosphates are known. It is largely employed in the manufacture of *aniline* colours and in preserving skins of animals. With H, As forms three compounds corresponding to P_2H, PH_2, and PH_3; the latter, AsH_3, *arsenetted hydrogen*, is formed by the union of its constituents in the nascent state (143). It is a colourless gas of a highly offensive odour; very poisonous; s. g. 2695; liquid at —40°; is decomposed into its constituents at a red heat.

AsH_3 is probably the most poisonous substance known; death has occurred from the inhalation of a quantity which must have been inappreciable to the balance. There is no direct antidote; the inhalation of chlorine would probably be of service.

With S, As forms AsS_2, *Realgar*, a red solid, and *Orpiment*, AsS_3, King's yellow, *Sulpharsenious* acid; both are used as paints and in fireworks; they are sulphur acids. AsS_5, *Sulpharsenic acid*, is also known. With Cl, As forms the volatile $AsCl_3$, which below 270° is liquid, but is not known as a solid; it is sometimes used in medicine. $AsCl_5$ is unknown; AsI_3 is the officinal iodide. The metal is officinal as *Arsenicum*.

Med. Effects.—The preparations of As are tonic, antiperiodic, antispasmodic, and alterative.

354. **Oxide**, *Acidum Arseniosum*, AsO_3, White Arsenic, Arsenic, Rats-bane. Sublimed Arsenious Acid, in masses, U. S. P. It is obtained, on the large scale, by roasting the ores which contain the metal; after which it is purified by sublimation.

Prop.—Is found in two distinct varieties: 1. The transparent or vitreous variety is an amorphous, colourless glass; s. g. 3·2 to 3·8. Is more soluble than the opaque variety, into which it gradually passes upon exposure to the air. 2. The opaque variety crystallises in regular octohedra (1st system), or very rarely in right rhombic prisms (3d system), of a milk-white colour, slightly heavier than the transparent, into which it passes by long boiling. Arsenious acid is tasteless and inodorous; it dissolves sparingly in cold water, 1 part dissolving in from 50 to 480 parts of water. In boiling water, both varieties are equally soluble, 1 part dissolving in from 7·72 to 24 parts. The boiling solution deposits the greater part upon cooling, but retains more than if the acid were simply added to cold water—about 1 in 30. The solution is tasteless. The solid acid sublimes at 425°, giving no garlicky odour, unless in the presence of reducing agents; it condenses on a cold surface, in crystals.

Adulterations.—When in *powder*, arsenious acid may be adulterated with chalk or flour. It should be entirely sublimed by heat.

Med. Effects.—Those of the preparations of arsenic generally. Dose, gr $\frac{1}{16}$ to $\frac{1}{10}$, in pill or solution. Externally, a powerful escharotic; there is danger of its absorption when thus used.

Toxicological Effects.—Depend upon the quantity; in large doses, the symptoms are those due to a violent irritant, and vary in different cases, the nervous system being often affected; they appear in from one minute to ten hours; death ensues, in fatal cases, in from 2½ hours to 3 days; the minimum quantity necessary to destroy life at a single dose is two grains; cases have recovered after taking an ounce. Post-mortem examination reveals inflammation, ulceration, and gangrene of the stomach and intestines. In small doses long continued, or after large doses from which death has not resulted, there is irritation and itching of the eyes and eyelids; conjunctivitis, œdema, irritability of the stomach, eczematous eruption, desquamation of the cuticle, loss of the hair, emaciation, salivation, and paralysis. The symptoms have been mistaken for those of cholera, perforation of the intestine, gastritis, etc.

It is now a well-established fact that there exists in Styria a class of *arsenic-eaters* who consume arsenious acid regularly and in quantities usually considered sufficient to produce death. It is known as *Hidrach*. A well-authenticated case is given in which a man of 30 years of age ate on one day 4½ grains at once, and on the next day 5½; arsenic was found in the urine, but no ill effects were perceived.*

Antidotes.—1. Hydrated Sesquioxide of Iron (Ferric hydrate); it should be freshly precipitated and freely given, a tablespoonful of the magma every 5 or 10 minutes, until the urgent symptoms are relieved; it acts, by giving a portion of O to the arsenious acid, converting it into Arsenic A., which forms an insoluble basic compound with the protoxide of iron, $2Fe_2O_3+AsO_3=4FeO,AsO_5$.

2. In the absence of this, *Ferri Subcarb.* may be given, but is often inert, from having been overheated.

3. Magnesia, recently precipitated, or recently and not too highly calcined, has been found efficient.

355. *Tests.*—(*a*) When solid. 1. Heat to redness in a

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* Dr. H. E. Roscoe, *Trans. Manchester Literary and Philos. Soc.*, Oct. 30, 1860.

glass tube, closed at one end, with fragments of charcoal, or powdered and dried, K_2Cfy; the AsO_3 is reduced, the metallic arsenic sublimed, and forms the arsenical mirror or ring in the tube at some distance from the flame. By breaking the tube, and allowing free access of air, the metal is oxidised again into AsO_3, and may be submitted to other tests; the octohedral crystals of AsO_3 may be seen in the second sublimate; the mirror must be distinguished from that produced by antimony, which is always deposited just beyond the red-hot part of the tube (see *Test* 6).

2. Arsenious Acid thrown upon live coals or other reducing agents, exhales a peculiar garlicky odour, which is not perceived when it is sublimed from a clean surface; it is probably due to the formation of suboxide.

(*b*) In solution. 3. Ammonio-Nitrate of Silver gives a rich yellow precipitate of arsenite of silver, $2AgO,AsO_3$, soluble in excess of ammonia, and in nitric, tartaric, acetic, and citric acid, but not in caustic potassa or soda; a solution of an alkaline phosphate precipitates yellow with nitrate of silver, and a dilute solution of phosphoric acid with the ammonio-nitrate. These are discriminated by the application of the other tests.

4. Ammonio-Sulphate of Copper gives a brilliant yellowish-green precipitate of arsenite of copper (Scheele's Green, $2CuO,AsO_3$), soluble in acids and in excess of ammonia, but not in potassa or soda; acetic and malic acids give also green precipitates with the ammonio-sulphate of copper, as do certain complex organic mixtures (Taylor).

5. Hydrosulphuric Acid, HS, gives a golden-yellow precipitate (orpiment, AsS_3), soluble in alkalies; the solution should be therefore slightly acidulated by acetic acid before trial; other metals (antimony, tin, uranium)

give somewhat similar precipitates; they are distinguished by their behaviour with other tests.

6. Marsh's Test. Add the suspected liquid to *pure* zinc, and dilute HO,SO_3; a little alcohol is useful to check frothing. Arsenetted hydrogen (AsH_3) is generated, which may be known by its odour, its violet-coloured flame, and by the metallic stain deposited upon a cold, white surface; or the gas may be passed through a long tube drawn out, heated at its centre; the metal deposits as in the reduction test, and may be further examined; or the gas may be passed into a solution of AgO,NO_5, metallic silver precipitates and AsO_3+HO,NO_5 remain; $6(AgO,NO_5)+AsH_3+3HO=\underset{\downarrow}{Ag_6}+AsO_{3\rightarrow}$, and $6(HO,NO_5)_{\rightarrow}$. The utmost care is necessary to avoid inhaling the gas. It may be absorbed by a solution of nitrate of silver, or by fuming nitric acid.

Antimonetted Hydrogen, SbH_3?, gives similar spots from the reduction of the metal; they may be distinguished, 1. By nitric acid, which converts the metallic arsenic into AsO_5, which is *soluble* and gives a brick-red precipitate with ammonio-nitrate of silver, while antimony is converted into *insoluble* antimonic acid. 2. The spot is heated to 500° by an oil-bath; if arsenic, it disappears; if antimony, it remains. 3. Hypochlorite of Soda dissolves arsenical spots, but does not affect those of antimony. 4. Tincture of Iodine instantly dissolves arsenic spots, leaving, on spontaneous evaporation, a lemon-yellow spot. Antimony is not immediately altered on evaporation; is converted after a time into orange-coloured iodide. 5. Vapour of Phosphorous Acid (PO_3) causes the disappearance of As spots in 4 or 5 hours; Sb spots remain a fortnight, but finally disappear.

7. Reinsch's Test. A bright slip of copper, or fine copper gauze, is boiled in the suspected solution, previously

acidulated with HCl; the metal precipitates upon the copper, forming an alloy, from which it may be volatilised and submitted to other tests; this process has these advantages: 1. It will act in the presence of organic matter; 2. It gives the metal in condition to be submitted to all the other tests. The reaction is prevented for a time by the presence of a nitrate or a chlorate.

Appreciation of these Tests.—No single test is to be relied upon, and, wherever practicable, all should be applied. The relative delicacy of the tests is given by Devergie as follows: Ammonio-sulphate of copper, 5,200; Sulphuretted hydrogen, 209,000; Ammonio-nitrate of silver, 400,000. By the latter, the $\frac{1}{8000}$ to the $\frac{1}{10000}$ of a grain may be rendered evident, if dissolved in but a drop or two of water; in one fluid-drachm of water, it detected the $\frac{1}{173}$ of a grain. Marsh's Test will detect, according to Danger and Flandin, the $\frac{1}{2000000}$ part of the liquid examined; according to Signoret, the $\frac{1}{200000000}$. Villain states that one grain will give, on an average, 226 metallic deposits, of an average diameter of $\frac{1}{12}$ of an inch, or will detect about the $\frac{1}{15000}$ of a grain. Reinsch's Test will detect, when the arsenic forms the $\frac{1}{90000}$ of the liquid, or the $\frac{1}{4000}$ of a grain (Taylor).

Remarks.—The wide diffusion of As, which is often found in commercial zinc, sulphuric acid, muriatic acid, and copper, renders it necessary that the reagents should be themselves carefully tested before using. *Organic matter* renders the liquid tests almost valueless, and causes so much frothing in Marsh's apparatus as to seriously interfere with its use. The best process for its separation is that of Taylor. The dried suspected matter is mixed with pure dilute HCl and distilled to dryness into a cooled receiver containing distilled water, and if necessary redistilled. The distillate contains $AsCl_3$ and free HCl; it may be diluted, and, by Marsh's or Reinsch's test, the As obtained in a convenient form for further investigation. AsO_3 may be separated from the contents of a stomach by dialysis; the organ itself serving as a dialyser (128). It is important to estimate the *quantity* present, as arsenic is given medicinally, and is sometimes found in paper, candles, potable waters, etc. This is best done by precipitating a given portion of the suspected liquid by HS, redissolving in HCl, and reprecipitating, washing, drying, and weighing 124 grains of AsS_3=100 grains AsO_3. It is a remarkable fact that there exists a compound freely soluble in water, which contains over 50 p. c. of arsenic, yet which is not poisonous, Kakodylic Acid, $(C_4H_6As)O_3,HO$.)

Arsenites.

356. *Liquor Potassæ Arsenitis*, Fowler's solution.

Prep.—Boil in f℥xii *Aquæ Destillat.* gr lxiv each of *Acid. arsenios.* in small pieces, and *Potass. bicarb.* until the former is entirely dissolved; then add f℥ss *Spirit. Lavand. Co.* and *Aquæ Destillat.* q. s. to make Oj. The solution probably contains $2KO,AsO_3$. The Spirit of lavender is added to give colour and taste, but decomposes and gives rise to a sediment; hence when in careful hands it may be replaced by an equal quantity of distilled water. The solution is then without colour and almost tasteless, its reaction is alkaline. Fowler's solution is the preparation of arsenic most usually prescribed; it contains gr iv *Potassæ Arsenitis* to f℥j. Dose, gtt v to xx. *Antidote*, the ferric salts; the ferric hydrate is useless. *Arsenites of Copper. Scheele's green*, $2CuO,AsO_3$, and *Schweinfurth* or emerald green; Aceto-arsenite of Copper; $2CuO,AsO_3+CuO,C_4H_3O_3$. These two compounds are largely used in the arts on account of their brilliant colour; wall-paper, artificial flowers and wreaths are coloured with the latter; the former has even been used in colouring toys and confectionery. Cases of death from their use in this way are recorded. The following is a simple test: Immerse the paper or other body in solution of ammonia, a deep blue liquid will be formed; pour a portion of this upon some crystals of AgO,NO_5 in a porcelain capsule, the presence of AsO_3 will be indicated by a yellow tinge on their surface. Or the paint may be scraped off and submitted to the reduction test.

357. *Iodide of Arsenic, Arsenici Iodidum, AsI_3.* Is made by gently heating together gr lx of powdered metallic Arsenic and gr ccc of Iodine. It is an orange-red, crystalline solid, insoluble in water, and wholly volatilised by heat. Its only use is in the preparation of Donovan's solution. *Liq. Arsenici et Hydrargyri Iodidi* (367).

ANTIMONY, Sb=122.

358. *Sources.*—The native sulphide SbS_3; is obtained by roasting and reduction.

Prop.—A brittle metal, s. g. 6·8, crystallising in rhombohedra (6th system), fusing at 1150°, and volatile at a white heat; burns with a brilliant white flame, forming SbO_3. Does not oxidise in the air; is attacked and dissolved by hot HCl and cold *Aqua regia;* nitric acid oxidises it to antimonic acid, $4HO,SbO_5$, which is insoluble in that menstruum.

Chem. Rel.—Resembles As in most of its compounds. Its oxides are: SbO_3, a feeble base, forming salts with Tartaric acid only; SbO_5, antimonic acid; and an intermediate oxide, SbO_4, or SbO_3,SbO_5. With H, it forms SbH_3, resembling closely AsH_3, which, when passed into a solution of AgO,NO_5, throws down solid antimonide of silver, Ag_3 Sb; $SbH_3+3(AgO,NO_5)=\underset{\downarrow}{AgSb_3}+3(HO,NO_5)\rightarrow$ Forms two sulphides, SbS_3 and SbS_5, which are soluble in alkaline solutions. The terchloride $SbCl_3$ and pentachloride $SbCl_5$ are decomposed by excess of water.

Tests.—Its few soluble compounds give an orange-red precipitate with HS, soluble in HCl, which solution is decomposed by water, affording a white precipitate of oxychloride, $2SbO_3,SbCl_3+HO$, which is coloured orange by NH_4S,HS. It may also be submitted to Marsh's and

Reinsch's tests, after the manner of arsenic. In the former case, a portion of metallic antimony is precipitated by the zinc in the form of a black powder; in the latter, the Sb may be dissolved from the copper by boiling KO, HO, the solution acidulated by Tartaric acid, and the characteristic reactions obtained. In cases of poisoning it may, if absent from the stomach, be detected sometimes in the urine and tissues.

359. **Oxide**, *Antimonii Oxidum*, SbO_3.

Prep.—*Antimonii Sulphuret.* (SbS_3) in fine powder ℥iv is dissolved by the aid of heat in ℥xviii of *Acid. Muriat.*; HS is evolved; $SbS_3 + 3HCl = SbCl_3{\rightarrow} + 3HS\uparrow$. To the chloride thus formed, ℥j gr cxx *Acid. Nitric.* is added, to decompose any remaining HS. It is then diluted with Oss *Aquæ* and filtered. This quantity of water is insufficient to cause decomposition. The filtrate is then thrown into Oxii *Aquæ* and stirred, the precipitate allowed to subside, strained and washed. It is the oxychloride *Powder of Algaroth*, $2SbO_3,SbCl_3 + HO$. This is treated for two hours with f℥iss *Aquæ Ammoniæ*, which converts the terchloride into teroxide. This is washed with distilled water until the washings no longer give a precipitate with AgO,NO_5 (absence of $SbCl_3$ or of NH_4Cl).

Prop.—A grayish-white powder, insoluble in HO, soluble in HCl and Tartaric acid, $2HO,C_8H_4O_{10}$. It fuses at a dull red heat, forming a yellowish liquid, which concretes on cooling into a pearl-coloured crystalline mass. Its solution in Tartaric acid should give no precipitate with AgO,NO_5 (absence of chlorides), or K_2Cfy (absence of iron, copper, etc.). Is used in the preparation of Tartar emetic.

360. **Sulphides**, *Antimonii Sulphuretum*, SbS_3; Native Tersulphuret (tersulphide) of Antimony, purified by fusion. U. S. P.

Prop.—A metallic-looking, steel-gray, fibrous, brittle, fusible substance; soluble in HCl with evolution of HS, and in alkalies and their carbonates. The orange-red precipitate obtained by the action of HS upon a solution of SbO_3 has the same constitution, but is probably amorphous. The tersulphide is rarely, if ever, employed in medicine.

Antimonii Oxysulphuretum, Kermes mineral.

Prep. — Dissolve ℥xxiii *Sodæ carb.* in Oxvi *Aquæ bullientis;* to this add ℥j *Antimonii Sulphuret., pulv. subtillis.*, and boil for an hour; filter quickly into a warm earthen vessel, which allow to cool slowly; at the end of 24 hours drain the precipitate and wash it with cold, boiled water; dry without the aid of heat. The reaction here is somewhat obscure. SbS_3, boiled with NaO,CO_2, forms some NaS and SbO_3; the former dissolves a fresh portion of SbS_3, and the latter is dissolved by the remaining NaO,CO_2. When the liquid cools, the tersulphide SbS_3, and teroxide SbO, precipitate together, forming the *Kermes mineral.*

Prop. — A purplish-brown, tasteless powder, soft and velvety to the touch, freely soluble in HCl with evolution of HS; partially (SbS_3) soluble in hot KO,HO, leaving a residue (SbO_3) soluble in Tartaric acid. Is sometimes used as a nauseant and diaphoretic and alterative. Dose, gr j to x.

Antimonium Sulphuratum, Precipitated Sulphuret (Sulphide) of Antimony.

Prep. — By dissolving ℥vi *Antim. Sulphuret. pulv. subtillis.* in Oiv *Liquor Potassæ*, adding *Aquæ Destillat.* q. s. during the boiling (2 hours) to keep up the measure; the hot liquid is rapidly strained through a double muslin strainer, and, while yet hot, *Acid. Sulph. dilut.* is gradually dropped in as long as a precipitate falls. This is washed with hot water. The product is a variable mixture of Kermes mineral with pentasulphide of antimony, SbS_5, (*Sulphur auratum*, Golden sulphur).

Reinsch's tests, after the manner of arsenic. In the former case, a portion of metallic antimony is precipitated by the zinc in the form of a black powder; in the latter, the Sb may be dissolved from the copper by boiling KO, HO, the solution acidulated by Tartaric acid, and the characteristic reactions obtained. In cases of poisoning it may, if absent from the stomach, be detected sometimes in the urine and tissues.

359. **Oxide**, *Antimonii Oxidum*, SbO_3.

Prep.—*Antimonii Sulphuret.* (SbS_3) in fine powder ℥iv is dissolved by the aid of heat in ℥xviii of *Acid. Muriat.*; HS is evolved; $SbS_3 + 3HCl = SbCl_3 \rightarrow + 3HS \uparrow$. To the chloride thus formed, ℥j gr cxx *Acid. Nitric.* is added, to decompose any remaining HS. It is then diluted with Oss *Aquæ* and filtered. This quantity of water is insufficient to cause decomposition. The filtrate is then thrown into Oxii *Aquæ* and stirred, the precipitate allowed to subside, strained and washed. It is the oxychloride *Powder of Algaroth*, $2SbO_3,SbCl_3 + HO$. This is treated for two hours with f℥iss *Aquæ Ammoniæ*, which converts the terchloride into teroxide. This is washed with distilled water until the washings no longer give a precipitate with AgO,NO_5 (absence of $SbCl_3$ or of NH_4Cl).

Prop.—A grayish-white powder, insoluble in HO, soluble in HCl and Tartaric acid, $2HO,C_8H_4O_{10}$. It fuses at a dull red heat, forming a yellowish liquid, which concretes on cooling into a pearl-coloured crystalline mass. Its solution in Tartaric acid should give no precipitate with AgO,NO_5 (absence of chlorides), or K_2Cfy (absence of iron, copper, etc.). Is used in the preparation of Tartar emetic.

360. **Sulphides**, *Antimonii Sulphuretum*, SbS_3; Native Tersulphuret (tersulphide) of Antimony, purified by fusion. U. S. P.

Prop.—A metallic-looking, steel-gray, fibrous, brittle, fusible substance; soluble in HCl with evolution of HS, and in alkalies and their carbonates. The orange-red precipitate obtained by the action of HS upon a solution of SbO_3 has the same constitution, but is probably amorphous. The tersulphide is rarely, if ever, employed in medicine.

Antimonii Oxysulphuretum, Kermes mineral.

Prep. — Dissolve ℥xxiii *Sodæ carb.* in Oxvi *Aquæ bullientis;* to this add ℥j *Antimonii Sulphuret.*, *pulv. subtillis.*, and boil for an hour; filter quickly into a warm earthen vessel, which allow to cool slowly; at the end of 24 hours drain the precipitate and wash it with cold, boiled water; dry without the aid of heat. The reaction here is somewhat obscure. SbS_3, boiled with NaO,CO_2, forms some NaS and SbO_3; the former dissolves a fresh portion of SbS_3, and the latter is dissolved by the remaining NaO,CO_2. When the liquid cools, the tersulphide SbS_3, and teroxide SbO, precipitate together, forming the *Kermes mineral.*

Prop. — A purplish-brown, tasteless powder, soft and velvety to the touch, freely soluble in HCl with evolution of HS; partially (SbS_3) soluble in hot KO,HO, leaving a residue (SbO_3) soluble in Tartaric acid. Is sometimes used as a nauseant and diaphoretic and alterative. Dose, gr j to x.

Antimonium Sulphuratum, Precipitated Sulphuret (Sulphide) of Antimony.

Prep. — By dissolving ℥vi *Antim. Sulphuret. pulv. subtillis.* in Oiv *Liquor Potassæ*, adding *Aquæ Destillat.* q. s. during the boiling (2 hours) to keep up the measure; the hot liquid is rapidly strained through a double muslin strainer, and, while yet hot, *Acid. Sulph. dilut.* is gradually dropped in as long as a precipitate falls. This is washed with hot water. The product is a variable mixture of Kermes mineral with pentasulphide of antimony, SbS_5, (*Sulphur auratum*, Golden sulphur).

CYANIDE: *Hydrargyri Cyanidum*, HgCy, Fulminate, $2Hg_2O,Cy_2O_2$, Percussion powder.

NITRATES:

Liquor Hydrargyri Nitratis, HgO,NO_5, with excess of HO,NO_5.

Unguentum Hydrargyri Nitratis, Citrine ointment.

SULPHATES: Hg_2O,SO_3; HgO,SO_3.

Subsulphate, *Hydrargyri Sulphas flava*, $3HgO,SO_3$, Turpeth mineral.

363. *Sources.*—The native sulphide *Cinnabar*, from which it is obtained by distilling with lime or iron filings.

Prop.—When pure, is a brilliant, silvery liquid, without taste or smell; s. g. 13·6; when finely divided, as in blue mass or precipitated mercury, is grayish and dull. At common temperatures, is unchanged in the air; heated above 600°, it slowly absorbs O, and becomes converted in red, HgO; at a higher heat, this is again resolved into Hg and O. It boils at 662°, and freezes at —39°, shrinking, and forming a lead-like solid. Commercial mercury contains other metals, as lead, tin, bismuth; it then tarnishes, and the globules are imperfect, having *tails*. It may be partially purified by the action of dilute HO,NO_5, Fe_2Cl_3, or HgCl, or by distillation. When required absolutely pure, it must be distilled from the sulphide.

Chem. Rel.—Mercury forms alloys with the metals generally termed *amalgams*. That with tin is used for coating looking-glasses; those with silver and gold, for fire-gilding and plating. It is also used to obtain the latter metals from their crushed *matrices* when they are in too small quantity to be separated by washing. It forms two sets of binary compounds, one containing two eq. of Hg to one of an electro-negative element; the other, one eq. of each. The latter *proto*-compounds are more energetic in their effects, and of brighter colour, than the former. The dioxide, Hg_2O (black or gray oxide), is obtained by precipitating calomel with lime water (ʒij to Oj, forming the *black wash*), $Hg_2Cl + CaO,HO = \underset{\downarrow}{Hg_2O}, + CaCl_{\rightarrow} + HO_{\rightarrow}$. It forms a series of unimportant salts. It is no longer officinal. The protoxide (red oxide), HgO, *Hydrargyri oxidum rubrum*, also forms a series of salts more stable than the former. The disulphide, black sulphide, *Æthiop's mineral*, is made by rubbing together Hg and S, and is a black, nearly inert powder of uncertain constitution; it generally contains an excess of sulphur. It is no longer officinal. The other compounds of mercury will be considered under the head of its preparations.

The equivalent of Hg was formerly assumed as 200; it has latterly been halved. If we combine 200 grains of mercury with 126·5 grains of iodine, we get the green iodide; 100 grains of the metal with the same of I, gives the red iodide. If Hg be assumed as 100, the former will be Hg_2I, and the latter HgI; if at 200, the former will be HgI, and the latter (doubled) HgI_2. The change of the equivalent only changes the nomenclature of the compounds; it cannot affect their character or reactions. As the U. S. Pharmacopœia does not use the chemical names of the preparations of mercury, but distinguishes them by some physical property, if the officinal titles are always used, no mistakes can occur.

Med. Effects.—Purgative, alterative, etc. Workmen exposed to its vapours, and persons using its preparations for a long time, become salivated, and are afflicted with tremors and *caries*. Iodide of potassium converts it into a compound soluble in excess of KI, which may after a time be eliminated with the secretions. For its effects in poisonous doses, see CORROSIVE SUBLIMATE.

364. **As Metal.**—(*a*) *Hydrargyrum*.

(*b*) *Pilulæ Hydrargyri*, Blue Pills.

Prep.—By rubbing ℥j *Hydrarg.* with ℥iss *Confect. Rosæ* until the globules disappear, and adding ℥ss *Pulv. Glycyrrhizæ* to make a mass to be divided into 480 (3 gr) pills.

Is generally made on the large scale, and rarely contains the full proportion of 33⅓ p. c. of mercury.

(*c*) *Unguentum Hydrargyri*, Blue ointment.

Prep.—By rubbing ℥xxiv *Hydrarg.* with ℥xii *Sævi* and q. s. *Adipis* until the globules are extinguished, and then adding the remainder of ℥xii *Adipis*. Is generally prepared on the large scale.

(*d*) *Emplastrum Hydrargyri.*

Prep.—By rubbing *Hydrarg.* (℥vi) with equal parts (℥ij) *Ol. Olivæ* and *Resinæ*, previously melted together and cooled, until the globules disappear, and adding these to (℥xii) *Emp. Plumbi*, previously melted, and mixing. Mercury is also employed in the

(*e*) *Emplast. Ammoniaci cum Hydrargyro.*

(*f*) *Hydrargyrum cum Cretâ.*

Prep.—By rubbing (℥iij) *Hydrarg.* with (℥v) *Cretæ Præparatæ* until the globules disappear. It combines the antacid effects of the chalk with the alterative powers of the mercury. There is too little chalk to be of much service; more may be added at the time of prescribing. When long kept, the mercury oxidises.

365. **Oxide**, HgO; *Hydrargyri Oxidum Rubrum*, Red Precipitate.

Prep.—By heating HgO,NO_5 until red fumes (NO_4) cease to arise. Also by heating mercury to near its boiling-point (*præcipitatum per se* of the older chemists), and as yellow hydrate by adding HgCl to lime water, $HgCl + CaO,HO = \underset{\downarrow}{HgO},HO + CaCl\rightarrow$. In the proportion of gr xxx to Oj, this forms the *yellow wash.*

Prop.—Brilliant red scales soluble in 7000 parts water, entirely dissolved by HCl, and decomposed and dissipated by heat. It is not employed internally.

Ung. Hydrargyri Oxidi Rubri.—℞. *Hydrarg. oxid. rub.* gr xxx, *Ung. Adipis* ℥j. M. *Ft. ung.* Used as a stimulant application. The precipitated oxide is preferable for making this preparation on account of its being amorphous, and in fine powder.

Sulphide, *Hydrargyri Sulphuretum Rubrum,* Cinnabar, Vermilion, HgS.

Prep.—Melt ℥viii *Sulphuris;* add to it, with constant stirring, ℥xl *Hydrarg.;* continue the heat until the mass begins to swell, cover the vessel and allow it to cool; then powder and sublime.

Prop.—In heavy, brilliant red, fibrous masses, insoluble in acids except *Aqua regia.* Is entirely volatilised by heat. Is used in fumigations; largely in the arts as a pigment.

366. **Chlorides.**

The two most important, *Calomel* Hg_2Cl, *dichloride,* and *Corrosive Sublimate* $HgCl$, *protochloride,* are conveniently considered together as far as their manufacture is concerned. *Corrosive Sublimate* is prepared as follows: ℥xxiv *Hydrarg.* are boiled with ℥xxxvi *Acid. Sulphuric.,* $Hg+2HO,SO_3=HgO,SO_3+SO_2\uparrow$. The sulphate of the protoxide thus formed is a white powder decomposed by water; it is mixed with ℥xviii *Sodii Chlorid.* and sublimed, $HgO,SO_3+NaCl=NaO,SO_3+HgCl\uparrow$; the former remains, the latter condenses in the head of the alembic. In making *Calomel,* the HgO,SO_3 is rubbed with an additional equivalent ℥xxiv *Hydrarg.,* forming Hg_2O,SO_3, sulphate of the dioxide. This is sublimed as before, $Hg_2O,SO_3+NaCl=NaO,SO_3+Hg_2Cl\uparrow$. It is carefully washed with boiling water until the washings give no precipitate with *Aqua Ammoniæ* (absence of $HgCl$). These compounds are generally made on the large scale.

(*a*) *Hydrargyri Chloridum mite;* Calomel.—Is a white, or pale-buff powder, insoluble in water, alcohol, and ether, entirely volatilised by heat; s. g. 7·2. Is not poisonous in large doses.

Incompatibles.—Alkalies, alkaline earths, their carbonates, soap, nitromuriatic acid, the chlorides ?, hydrocyanic acid.

(*b*) *Hydrargyri Chloridum corrosivum;* Corrosive Sublimate, HgCl.—Is in colourless, transparent crystals (3d system), or white, semi-transparent, crystalline masses; s. g. 5·2; permanent in the air. It is inodorous, of an acrid, persistent, metallic taste; melts and volatilises readily, with dense, acrid fumes; soluble in 20 parts cold and 3 boiling water, in alcohol and ether; also, without change, in sulphuric, muriatic, and nitric acids; muriate of ammonia, and common salt, render it more soluble in water. It retards putrefaction by coagulating albumen and fibrin. Should dissolve wholly in ether, and be wholly volatilised by heat. Dose, gr $\frac{1}{12}$ to $\frac{1}{16}$.

Incompatibles.—Alkalies, alkaline earths, their carbonates, soap, iodides, sulphides, tartar emetic, nitrate of silver, acetates of lead, and many metals, vegetable astringents, albumen, fibrin, gluten.

Toxicological Effects.—In overdose, gr iii to v, a corrosive poison; recovery has taken place after an ounce had been swallowed. Antidotes: Albumen (white of egg, blood), fibrin, gluten (flour), milk, with free evacuation of the stomach; Quévennes iron or iron filings wrapped in gold leaf. *Tests.* (1) When in powder, KI produces a bright scarlet colour, NH_4S,HS a black; NH_4O does not alter it. (2) In *solution,* KI a yellow precipitate, changing to scarlet, NH_4O a white, and SnCl a gray (precipitated mercury). A bright slip of copper immersed becomes silvery from the deposition of Hg, which may be afterwards sublimed in characteristic globules. (3) In *organic mixtures,* HgCl is soluble in ether, and can thus often be extracted along with fatty matters, which are separated by water; it may then be submitted to tests (2). If a slip of gold foil, intertwined with zinc, be introduced, voltaic action will precipitate the Hg on the former; it may be dissolved by HO,NO_5 and submitted to SnCl, or a portion volatilised and the characteristic globules obtained. This test proves the presence of mercury, but not that it is in the form of HgCl.

(*c*) *Hydrargyrum Ammoniatum*, $HgCl,HgNH_2$, Chloramide of mercury; White precipitate.

Prep.—By dissolving ℥vi *Hydrarg. Chlorid. corros.* in Oviii *Aquæ Destillatæ* by the aid of heat, adding *Aquæ Ammoniæ* f℥viii with stirring; and washing and drying the precipitate. $2HgCl+2NH_4O=\overline{HgNH_2,HgCl}\downarrow+NH_4Cl_{\rightarrow}+HO$.

Prop.—A white, insoluble, heavy powder, decomposed by boiling with water and by a high heat. Is employed externally only; the *Ung. Hydrarg. Ammon.* contains gr xl to ℥j *Ung. Adipis.*

367. **Iodides.**

(*a*) *Hydrargyrum Iodidum viride*, Hg_2I; Diniodide.

Prep.—Mix in a mortar ℥j *Hydrarg.* with gr ccc *Iodinii* and add f℥ss *Alcohol. fortioris*, triturate until the ingredients are thoroughly incorporated; stir the mixture occasionally, and at the end of two hours rub again until nearly dry. Then rub with *Alcohol. fort.* to a thin paste, and wash with the same until the washings cease to produce a precipitate when dropped into water (absence of red iodide, HgI). Dry and keep it in the dark, in a well-stopped bottle. The alcohol facilitates the combination of the elements, and removes HgI.

Prop.—A greenish-yellow powder, becoming red when heated; soluble in ether; exposed to the light, it becomes of a dark olive colour. It combines the properties of its constituents; *dose*, gr j to iij. Is incompatible with *Potass. Iodid.*, which converts it into the red iodide, HgI.

Hydrargyri Iodidum rubrum, Protiodide, HgI.

Prep.—By double decomposition of *Hydrarg. Chlorid. corros.* ℥, dissolved in Ojss *Aquæ Destillat.*, and *Potass. Iodid.* ℥j gr cxx, in Oss *Aquæ Destillat.* The precipitate is washed, dried, and kept in a well-stopped bottle. $HgCl+KI=\underset{\downarrow}{HgI}+KCl_{\rightarrow}$. The precipitate is at first yellow, but becomes red.

Prop.—A brilliant, crystalline, scarlet powder, (2d and 4th systems), becoming yellow when heated, and having its colour restored by pressure. This is due to a change of crystalline form (123). It sublimes unchanged chemically. It dissolves in alcohol, also in solution of *Potass. Iodid.*, forming *Iodohydrargyrate of potassium*, KI,2HgI, which is valuable as a test for the alkaloids, and is given internally in the same cases as HgI. It is frequently formed extemporaneously in prescriptions in which corrosive sublimate and iodide of potassium are ordered together. The red iodide is much more active than the green. *Dose*, gr $\frac{1}{16}$, in alcohol, pill, or solution of *Potass. Iodid.*; in overdose, resembles corrosive sublimate, and requires similar treatment.

Bibron's antidote for snake-bites.—℞. *Hydrarg. Chlor. corros.* gr ij, *Potass. Iodid.* gr iv, *Brominii* gr ccc, *Alcohol dilut.* f℥viiss. Dose, gtt x in f℥ss *Spt. Vini Gallici*, repeated *pro re nata.*

Liquor Arsenici et Hydrargyri Iodidi; Donovan's solution.

Prep.—Rub gr xxv āā *Arsenici Iodidi et Hydrarg. Iodid. rub.* with f℥ss *Aquæ Destillat.*, and when dissolved add f℥viiss more and filter. It contains AsI_3 and HgI; has the properties of its three constituents. Is easily decomposed, and should be given alone; the quantity of arsenic is relatively small, being only about gr $\frac{1}{10}$ of metallic arsenic to f℥j. Dose, gtt v to x. In large doses, produces effects like those of Corrosive sublimate, and requires the same treatment.

369. **Cyanide**, *Hydrargyri Cyanidum*, HgCy.

Prep.—By distilling Hydrocyanic acid, HCy, into a receiver containing HgO, enough of the latter being used with agitation to destroy the odour of HCy. The solution is filtered and crystallised. $HgO+HCy=HgCy\rightarrow+HO_{\rightarrow}$.

Prop.—White, square, prismatic crystals (2d system), wholly soluble in water; gives off Cy by heat, leaving Hg and *paracyanogen*. On the addition of HCl evolves HCy, leaving HgCl. Is very rarely used in medicine. *Dose*, properties, and antidotes, those of corrosive sublimate.

Fulminate, $2Hg_2O,Cy_2O_2$. This substance, employed in percussion-caps, may be made by dissolving gr c Hg in f℥iss *Acid. Nitric.*, adding ℥ij *Alcohol*, and if necessary more to moderate the action; the fulminate precipitates, is washed and dried at a heat not exceeding 120°. It is very explosive, and should be kept under water. It evolves, when exploded, CO_2, N, and Hg.

370. **Nitrates.**

Nitric acid unites with the oxides of mercury to form seven compounds; only one of these, the normal nitrate of the protoxide, is important.

Liquor Hydrargyri Nitratis, Acid Nitrate of mercury, HgO,NO_5+xHO,NO_5.

Prep.—Dissolve ℥iij *Hydrarg.* in a mixture of ℥v *Acid. Nitric.* and fʒvj *Aquæ Destillat.* When red fumes cease to be evolved, evaporate to f℥viiss. $Hg_3+4(HO,NO_5)=3(HgO,NO_5)_{\rightarrow}+N\overset{\uparrow}{O}_2+4HO$. An excess of acid is present.

Prop.—A colourless, acid liquid, s. g. 2·165. It is not decomposed by an excess of distilled water. It reacts with KI, SnCl, and bright copper, like HgCl. Is used as a caustic.

Unguentum Hydrargyri Nitratis, Citrine ointment.

Prep.—℥jss *Hydrarg.* is dissolved in ℥iijss *Acid. Nitric.*, forming as above HgO,NO_5; this is added to ℥xii *Ol. Bubuli* and ℥viss *Adipis* melted together, and the whole stirred with a wooden spatula until the ointment stiffens. A complex change takes place, both the nitrate and the fats being partially decomposed. It is of a yellowish colour, offensive odour, and somewhat liable to change. Used in skin diseases.

371. Sulphates.

The sulphate of the protoxide HgO, and that of the dioxide Hg_2O, are prepared as a preliminary step in the manufacture of corrosive sublimate and calomel.

Subsulphate ; Hydrargyri Sulphas flava, Turpeth mineral.

Prep.—℥iv *Hydrarg.* are dissolved in ℥vi *Acid. Sulphuric.*, $Hg+2HO,SO_3=HgO,SO_3+SO_2+2HO_{\rightarrow}$; this is evaporated to dryness and thrown into boiling water, which decomposes it into yellow trisulphate and soluble tersulphate, $4(HgO,SO_3)=\underset{\downarrow}{3HgO,SO_3}+HgO,3SO_{3\rightarrow}$.

Prop.—A yellow powder, soluble in 2000 parts cold and 600 of boiling water; moderately heated, it becomes red, but regains its yellow colour on cooling. At a high heat it is decomposed, SO_2 and O being evolved, and metallic Hg sublimed. Is sometimes used as an errhine, and, rarely, internally as an emetic and alterative. Dose, gr ¼ to v. In overdose, a poison; the antidotes for HgCl may be employed.

SILVER (*Argentum*), $Ag=108$.

372. *Sources.*—Occurs native, and as sulphide, chloride, and iodide; also in the argentiferous galena. Is obtained by amalgamation and cupellation. Pure silver may be obtained from coin which contains 10 p. c. of copper, by dissolving in nitric acid, adding HCl or $NaCl$, which precipitates $AgCl$; this may be reduced by fusing with mixed carbonates of potassa and soda, with borax, or by immersing scraps of zinc or iron.

Prop.—A brilliant white, malleable, ductile metal, s. g. 10·5; fusible and volatile at a white heat, and burning with a green light in the voltaic arc; it does not oxidise by the action of ordinary oxygen, but is attacked by ozone. When melted, it takes up mechanically many volumes of O, which it ejects on cooling, causing the *spirting* or *spitting* of the metal. It tarnishes in air, owing to the formation of a superficial layer of sulphide.

Chem. Rel.—Forms Ag_2O, AgO, and AgO_2; AgO, only, is important. AgS is the black tarnish of silver; $AgCl$ is insoluble in water and acids, but soluble in ammonia, and blackens on exposure to the light. AgI and $AgBr$ are sensitive to light, and largely employed in photography. The metal is not easily attacked by acids, except the nitric. *Test.*—Soluble chlorides give a white, curdy precipitate of $AgCl$, which has the properties above given. It is reduced from solution by iron, copper, and zinc. Is officinal as *Argentum*.

373. **Oxide**, AgO, *Argenti Oxidum.*

Prep.—Dissolve ℥iv *Argenti Nitrat.* in Oss *Aquæ Destillat.*, and add *Liq. Potassæ* as long as a precipitate is produced; wash and dry the latter. $AgO,NO_5 + KO,HO = \underset{\downarrow}{AgO} + KO,NO_{5\rightarrow} + HO_{\rightarrow}$.

Prop.—An olive-brown powder, decomposed by heat into Ag and O; slightly soluble in water; having a faint alkaline reaction. By treatment with strong ammonia, which dissolves it in part, a black explosive powder is obtained, Ag_3N?; this is distinct from fulminate of silver, $2AgO,Cy_2O_2$, which is analogous to the corresponding mercury compound, but more explosive. AgO is used in medicine for the same purposes as the nitrate, over which it is supposed to have the advantage of not blackening the skin. *Dose*, gr ss to j.

374. **Cyanide,** *Argenti Cyanidum*, AgCy.

Prep.—By passing the vapour of HCy into AgO,NO_5, or by adding Cyanide of potassium, not in excess, to a solution of AgO,NO_5. $AgO,NO_5 + HCy = \underset{\downarrow}{AgCy} + HO,NO_{5\rightarrow}$.

Prop.—A tasteless, white, insoluble powder, soluble in KCy and in nitric acid; is employed for the extemporaneous formation of *Acid. Hydrocyanic. dilut.*

375. **Nitrates,** *Argenti Nitras*, AgO,NO_5.

Prep.—By acting on silver by nitric acid; $Ag_3 + 4(HO,NO_5) = 3(Ago,NO_5)_{\rightarrow} + \overset{\uparrow}{NO_2} + 4HO_{\rightarrow}$. If coin be employed, nitrate of copper will be present; on heating the solution to dryness, this will be decomposed, leaving insoluble CuO, from which the AgO,NO_5 may be separated by solution and filtration.

Prop.—Colourless, transparent crystals (3d system), of a metallic and bitter taste, soluble in their weight of cold water and 4 parts of cold alcohol. The salt is decomposed by heat, with a bright flame, leaving spongy metallic silver. It is blackened by the contact of organic matter.

Med. Effects.—In overdose, an irritant poison; antidote, common salt; in medicinal doses, gr $\frac{1}{4}$ to $\frac{1}{2}$, used in the neuroses and chronic gastritis; externally in collyria. Should not be mixed with other medicines, and, if given in pill, it should be made up with gum; if dissolved, distilled water should be used.

Argenti Nitras fusa, Lunar caustic, *Lapis infernalis*, AgO,NO_5. Is made by fusing the salt and pouring it into moulds. Is for external use. It sometimes contains chloride, which renders it less brittle; the latter will be left behind upon dissolving it in water. A stick of nitrate of silver may be conveniently pointed by rubbing it with a rotary motion upon a polished silver coin.

GOLD (*Aurum*), Au=98.

376. Occurs native; is, when pure, soft, yellow, and the most malleable of the metals; it can then be welded cold, and is used for filling teeth; s. g. 19·5; melts at a bright red heat; is unaltered in the air, and only attacked by *Aqua regia*, selenic acid, and nascent cyanogen. American coin contains 900-thousandths of pure gold. Its most important compound is the chloride $AuCl_3$, used in photography in *toning* prints. It gives with protochloride of tin a purple precipitate (Purple of Cassius, AuO,SnO_2,SnO,SnO_2+4HO ?) which is used in glass staining and in painting upon porcelain. Gold is precipitated from solution by ferrous sulphate, FeO,SO_3. Polished steel dipped into its ethereal solution acquires a coating of metallic gold on the evaporation of the ether. Fire-gilding is performed by heating a coating of amalgam of gold and mercury applied to the body, the mercury is driven off. Electro-gilding has been already described (166). The preparations of gold have been used in the treatment of syphilis, but are now abandoned. They are highly poisonous; the antidotes for mercury may be used.

PLATINUM, Pt=98·5.

377. Is a rare metal, occurring always native, in grains, and associated with other metals of the same group, Iridium, Osmium, Palladium, and Rhodium. Of these, the two first form a very hard alloy, *irid-osmine*, which is used for pointing gold pens. Osmium forms a poisonous, volatile, osmic acid, OsO_4. The grains of platinum may be dissolved in *Aqua regia*, and the metal precipitated by NH_4Cl, in the form of a yellow double chloride, $NH_4Cl, PtCl_2$, which on exposure to heat leaves the metal finely divided, *Platinum sponge;* this may be welded into sheets. Platinum black, another form of the finely divided metal, is made by adding KO,HO to $PtCl_2$, and then alcohol. Both of the forms of the metal are remarkable for their power of absorbing and condensing gases (147). The grains may also be fused together by the compound blowpipe, forming ingots, as first done by the late Dr. Hare.

Platinum is the heaviest metal known; s. g. between 21 and 22; is highly malleable and ductile, resists all ordinary chemical agents even at high temperatures; is harder than gold, and much used in the laboratory and the arts in the form of wire, foil, crucibles, and retorts. Like iron, it may be welded at a high heat. Its most important compound, the bichloride $PtCl_2$, is used as a test for potassa and as a means of getting its other preparations. It forms a remarkable series of double chlorides of much theoretical interest. Its compounds are not used in medicine.

PART IV.

ORGANIC CHEMISTRY.

378. **ORGANIC CHEMISTRY** investigates compounds produced under the influence of *vitality*, and those derivable from them by artificial means.

This definition, although convenient, is not accurate. Recent researches have shown that many bodies, formerly obtained from the organic kingdoms, may be produced artificially. The compounds of ammonia and cyanogen are no longer considered as organic. Formic acid, alcohol and its derivatives, many of the fatty acids, glycerine, taurine (found in the muscles of the mollusca), urea, oils of mustard and garlic, are examples of organic bodies which may be found of purely inorganic materials. We owe much of our knowledge on this subject to Berthelot, who, by imitating the gradual processes of nature, rather than the rapid and violent ones of the laboratory, has formed, from carbon obtained from the earthy carbonates, hydrogen from water, and oxygen from air, an extended and important series of artificial organic bodies. Instances of this organic synthesis will be given hereafter.

379. *Constitution of Organic Bodies.*—Few *elements* enter into the constitution of organic bodies, but the number of *equivalents* is great. Carbon is the essential element; next in frequency occurs Hydrogen, then Oxygen; a comparatively limited group contains Nitrogen; still more rare are Sulphur and Phosphorus; and finally, only in certain structures, or in artificially derived bodies,

do we find the other elements. The number of atoms is large. Morphia has the formula $C_{34}H_{19}NO_6+2HO$, and its equivalent is 303, against 47 for KO or 20 for MgO. Organic bodies also change in the most various and complex modes, differing much from those of the simple acids, bases, and salts which have been heretofore considered. The number of possible compounds can be shown to be infinite. Of the compounds of Glycerine with the known acids, Berthelot has shown* that over 200,000,000 are possible, and a similar variety will be shown to be probable under the head of *substitution compounds.*

380. *Decomposition.*—From their complexity, organic bodies are prone to decomposition; the elements rearranging themselves in simpler forms, hence we have as results ammonia, marsh gas, compounds of sulphur and hydrogen, cyanogen, etc. The following are the most important varieties of natural decomposition: *Eremacausis,* or decay, which occurs only in non-nitrogenised bodies, as wood, and which is a slow oxidation accompanied by absorption of nitrogen; *Fermentation,* occurring in non-nitrogenised bodies under the influence of a putrefying nitrogenised substance; *Putrefaction,* occurring only in bodies containing nitrogen; it is closely allied to fermentation.

381. *Analysis of Organic Bodies.*—1. Qualitative. Organic bodies contain carbon in excess of the quantity of O necessary to consume it. On heating them in a tube, the C remains. This is characteristic of organic matter. Water may be driven off by a heat of 212°. Mineral matters are determined by burning the body in a crucible, by the aid of KO,NO_5 or KO,ClO_5, and examining the ash. Use is made of the solvent powers of various menstrua in separating the *proximate* constituents, as in the simple example of a *gum-resin,* where the former is

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* *Chémie Organique fondée sur la Synthèse,* Tome ii. p. 33. Paris, 1860.

dissolved by water and the latter by alcohol. Fractional distillation is also usefully employed to separate bodies of different degrees of volatility. The other methods of distinguishing organic bodies, and of separating them into their proximate constituents, will be explained hereafter. The *Ultimate* analysis of organic bodies is effected by burning the body and weighing the products of combustion. This is generally effected by mixing the body, carefully dried and weighed, with CuO or PbO,CrO_3 in a tube, sealed at one end, and applying heat; the products of combustion are caused to pass through a tube containing fragments of fused $CaCl$, and then through bulbs filled with a solution of KO,HO. The former intercepts the watery vapour formed by the combustion of the H, and the latter the CO_2 formed by that of the C. The tube and bulb are weighed carefully before and after the combustion; $\frac{1}{9}$ of the increase of the weight of the former is H, and $\frac{3}{11}$ of the latter C. The O is estimated by the difference of the combined weight of these elements with the ash and that of the body analysed. The presence of nitrogen in an organic body is generally manifested by the evolution of NH_4O, when heated alone or with KO,HO; its amount may be determined by collecting it as it issues from the potash bulb. *Sulphur* is detected by heating the body with an alkali and testing with nitro-prusside of sodium; it may be burned into SO_3 and precipitated by Baryta. *Phosphorus* may be converted into phosphates and tested in that form.

382. *Theoretical Considerations.*—The result of ultimate analysis is merely a knowledge of the elements contained in a body, and their amounts *per cent.* We know nothing of the arrangement of the elements of any body, organic or inorganic. Theory supposes them to be arranged in a certain way for the purpose of conveniently arranging and studying the facts. Thus, sulphate of po-

tassa contains one atom of sulphur, one of potassium, and four of oxygen; we suppose these to be arranged as KO, SO_3; we may suppose them to be K,SO_4, or KO_2SO_2, or KO_3SO, or KO_4S, etc. We assume the former of these to be true from probability and convenience. Alcohol, $C_4H_6O_2$, may be regarded as C_4H_5O,HO, or C_4H_42HO, or $\left.\begin{matrix}C_4H_5\\H\end{matrix}\right\}O_2$, etc. The formula given by ultimate analysis is termed the *empirical* formula; that which represents the supposed arrangement, the *rational* formula.

Compound Radicals.—We assume the existence of compound bodies which, like ammonium (274) and cyanogen (235), act as elements; these are called *quasi elementary bodies* or *radicals;* they are exceedingly numerous. By far the largest number contain only C and H, the equivalents of the former being even and of the latter odd. They form oxides, hydrates, and compounds with the acids and halogens strictly analogous to the corresponding compounds of the metals.

Thus the radical Ethyl, C_4H_5, forms C_4H_5O, Ether, C_4H_5O,HO Alcohol, C_4H_5O,NO_3 Nitrite of the Oxide of Ethyl, C_4H_5Cl Chloride of Ethyl, etc. These cannot in many cases be made directly, and it should be remembered that the whole assumption is merely a convenient theory.

383. *Substitution Compounds.*—In inorganic chemistry, H is replaced by the metals, $HCl+Zn=ZnCl+H$; and the amphigens (184) and halogens (224) replace each other. In organic chemistry, not only do these replacements take place, the quasi metals or radicals being included as metals, but the halogens and NO_4 replace H. These *substitution* compounds often present a marked resemblance to those from which they are derived. Thus, Pyroxyline or gun-cotton, $C_{24},\frac{H_{14}}{(NO_4)_6}O_{20}$, made by the action of HO,NO_5 on cotton, $C_{24}H_{20}O_{20}$ has six of NO_4 in place of three of the H of the latter. The most remark-

able bodies of this group are to be found under the head of the substitution ammonias (425).

384. *Isomeric, Metameric, and Homologous Bodies.*—In inorganic chemistry, we have seen that the same elements in the same proportions produce the same compound. In organic chemistry, we have frequent instances of bodies of precisely the same composition, but of different chemical and physical properties. Thus: Cellulose (cotton) Starch, Dextrin, and Gum Tragacanth, all have the formula $C_{24}H_{20}O_{20}$. Such bodies are termed *isomeric* (Gr. *isos*, equal, *meros*, weight). Their widely different properties are attributed to a difference in the arrangement of their atoms. *Metameric bodies* (Gr. *meta*, beyond, *meros*, weight) are isomeric bodies of which the rational formulæ are supposed to have been determined, and thus this difference of arrangement made clear. Thus, Acetate of oxide of methyl $C_2H_3O,C_4H_3O_3$, Formate of oxide of ethyl C_4H_5O,C_2HO_3, and Propionic Acid $C_6H_5O_3,HO$, have each the empirical formula $C_6H_6O_4$. Homologous bodies (Gr. *homoios*, similar, *logos*, ratio) differ from each other by a fixed amount of C and H, and those belonging to the same series have generally a similarity of properties and chemical characters. Thus, the following acids, Formic C_2H,O_3HO, Acetic $C_4H_3O_3,HO$, Propionic $C_6H_5O_3,HO$, Butyric $C_8H_7O_3,HO$, increase by C_2H_2 or a multiple of it; their boiling-points have also been noticed to rise about 34° F. for each increase of C_2H_2. We have many such series.

385. ARRANGEMENT. — Organic bodies will be considered under the following heads:

1. The Starch group, including the sugars, gums, and woody fibre.
2. Radicals homologous with Ethyl, having the general formula $C_2nH_2n+_1$; their compounds and derivatives.

3. Radicals not homologous with Ethyl.
4. Organic Acids not oxides of known radicals.
5. Substitution Ammonias, the alkaloids and allied principles.
6. Fats and Oils.
7. Colouring Matters.
8. The proximate principles of animals and vegetables and otherwise classified, with the chemistry of the animal solids and fluids.

I. STARCH GROUP.

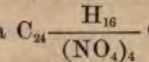
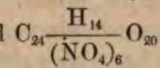
THE most important members of this group are:—

Cellulose,	$C_{24}H_{20}O_{20}$.
Starch,	$C_{24}H_{20}O_{20}$.
Dextrin,	$C_{24}H_{20}O_{20}$.
Gum Arabic,	$C_{24}H_{22}O_{22}$.
Gum Tragacanth,	$C_{24}H_{20}O_{20}$.
Pectin,	$C_{64}H_{48}O_{64}$.
Cane Sugar,	$C_{24}H_{22}O_{22}$.
Grape Sugar,	$C_{24}H_{28}O_{28}$.
Fruit Sugar,	$C_{24}H_{24}O_{24}$.
Milk Sugar,	$C_{24}H_{24}O_{24}$.

They all, except Pectin, contain the same proportion of C, and the H and O are in the proportions to form water. They have been termed Carbohydrates, but the word is objectionable; it cannot be assumed that they are composed of carbon and water.

386. **Cellulose,** $C_{24}H_{20}O_{20}$. Is the fundamental material of the structure of wood constituting the cell-wall. It is

seen nearly pure in fine linen, cotton wool, or fine unsized paper. It has been detected in certain diseased conditions of the human brain.

Cellulose is white, inflammable, insoluble in ordinary menstrua. It may be dissolved in the cold by a solution of ammonio-sulphate of copper (330), by strong alkalies at high temperatures and pressures, and it is decomposed by Cl and I. Cold HO,SO_3 converts it into *dextrin*, and finally into grape sugar; when pure, it is not immediately blackened by this reagent. By the immersion for half a minute in HO,NO_5, and washing, it is converted into explosive *gun-cotton*, or pyroxylin. A mixture of equal parts of commercial nitric and sulphuric acids, allowed to cool, will answer. A less explosive variety, freely soluble in ether, is made by the action on the cotton wool for 24 hours of a mixture of KO,NO_5, in fine powder ℥x, and sulphuric acid s. g. 1·843 ℥xvss. The formula  $C_{24}\frac{H_{16}}{(NO_4)_4}O_{20}$ has been assigned to the explosive, and  $C_{24}\frac{H_{14}}{(NO_4)_6}O_{20}$ to the soluble variety.

Collodion, *Collodium*, U. S. P., is a solution of pyroxiline gr lvi in a mixture of f℥iiiss of ether and f℥j of stronger alcohol. Its tendency to contract may be obviated by the addition of 5 to 10 p. c. of castor oil or Venice turpentine.

Explosive compounds resembling pyroxyline in composition have been made by the action of HO,NO_5 on starch, glucose, mannite, etc. By the action of FeCl or of KS,HS, pyroxiline is reconverted into cotton.

Wood consists of cellulose, with incrusting and other materials, to which the names of vasculose, fibrose, etc. have been given; they are grouped under the general term of *intercellulose*. By the action of caustic alkali under pressure, the intercellulose is dissolved and cellulose remains. Very strong alkaline lyes under pressure attack the cellulose. By the action of a mixture of caustic potassa and soda on sawdust, oxalic and finally ulmic acid ($C_{40}H_{14}O_{12}$) are formed. Cotton goods immersed in a cold, strong solution of caustic alkali are rendered thicker and stronger, a portion of the alkali entering into combination with the fibre. Unsized paper dipped for an instant into a mixture of 2 vols. HO,SO_3 and one of water, and then well washed, becomes converted into a parchment-like substance.

Decomposition.—Wood exposed to the air undergoes slow decay, *eremacausis*, due to the absorption of oxygen; carbonic acid and water are produced. This may be retarded by impregnating it with antiseptics, which coagulate the albuminous matters. The most important are, $ZnCl$, $HgCl$, CuO,SO_3, and coal-tar. In dry air, or *wholly* submerged, wood will last for centuries. Vegetable mould contains certain principles which have been described as *humus, geine, ulmin, geic, humic*, and *ulmic* acids; they sometimes contain ammonia, the nitrogen of which is supposed to have been obtained from the atmosphere.

When vegetable fibre undergoes decomposition, *partially* excluded from the air, either under water or ground, it is converted into *peat*, and gradually into *lignite* and *coal.*

By the *destructive distillation* of wood and coal, a variety of complex products are produced; these vary with the temperature, moisture present, etc. They may be classed as, (1) *Gases*, CO, CO_2, C_2H_4, C_4H_4, NH_4O, and C_2N; and volatile, complex, hydrocarbons, among which naphthaline, $C_{20}H_8$, a white crystalline body, solid at ordinary temperatures, may be mentioned. (2) *Tar*, which is a very complex body. Wood tar, *Pix liquida*, contains wood spirit $C_2H_4O_2$, acetic acid $C_4H_4O_4$, paraffine and creasote $C_{14}H_8O_2$. Wood spirit and acetic acid will be considered under Group II. *Paraffine* (*parum*, little, *affinis*) is a beautiful transparent solid, unaffected by any ordinary chemical agents. It is used in making candles, waterproofing, and for greasing the stoppers of chemical reagent bottles. It consists of C and H, but its formula has not been determined. Naphthaline, $C_{20}H_8$, is a white crystalline body, solid at ordinary temperatures. *Creasote*, Creasotum, $C_{14}H_8O_2$, is a colourless, oily liquid, of a burning caustic taste, and peculiar smell, is inflammable, boils at 397°. It coagulates albumen, and is antiseptic, as is seen in smoked meats. Is used externally, mixed with water, as a stimulant and detergent wash, and pure as a caustic; the *Unguent. Creasoti* contains fʒss *Creasoti* to ℥j *Adipis*. Creasote is sometimes given internally as an astringent and anti-emetic. *Dose*, gtt ss to j, in water. In overdose, is an irritant poison, *antidote*, albumen. *Carbolic* or *Phenic acid*, coal-tar, creasote, $C_{12}H_6O_2$, or $C_{12}H_5O,HO$, hydrate of the oxide of *phenyl* (417), closely resembles the former, and is perhaps identical. It is in transparent crystals, having the odour and other properties of creasote, and is soluble in water by the aid of acetic acid. Used in the same cases as the former. Ridgewood's *disinfectant* consists of carbolic acid, lime, and clay. Carbolic acid is one of the most reliable of the Antiseptics (199). *Coal-tar* gives on distillation *Naphtha*, which contains benzole, $C_{12}H_6$, and its homologues (417); *dead oil*, containing naphthaline, paraffine, and a residue of pitch. By chemical agents, the beautiful aniline dyes and other colouring and even fragrant matters are obtained from coal-tar. These will be discussed hereafter.

387. **Starch,** $C_{24}H_{20}O_{20}$.—Is obtained chiefly from the roots and seeds of vegetables, by mixing the crushed or rasped matter with cold water, which dissolves albuminoid matters, and allows the starch to fall to the bottom of the

vessel. It is also found in the brain, the liver and kidneys, spleen, and mucous surfaces. The following are the most important varieties of starch: corn starch, wheat starch (amylum), potato starch, *Maranta* (arrow-root), *Sago, Tapioca,* and Canna (*Tous le mois*).

Prop.—Is a white shining powder, exhibiting under the microscope irregular grains, the size of which varies; those of Canna measure the $\frac{1}{200}$ of an inch, those of Macanta $\frac{1}{600}$, of amylum $\frac{1}{1000}$, of rice $\frac{1}{3000}$. These grains consist of layers covered by an external membrane, each globule having on it a mark or *hilum*. It is insoluble in water, but when boiled, the membrane bursts, and the whole forms a transparent jelly, probably not a true solution, *amidin, clear starch;* this gives a characteristic blue colour with free iodine.

The starch from elecampane, etc., *Inulin*, and from lichens and algæ, *cetrarin, chondrin*, differs somewhat in composition from the ordinary starch. The former is coloured yellow, and the latter brownish-gray, by iodine.

Chemical Changes.—Dilute acids (except phosphoric), diastase, and saliva convert starch into *dextrin*. Cold strong nitric acid dissolves it; and, on the addition of water, a precipitate of *xyloidine*, an explosive body resembling pyroxyline, is deposited. Dilute nitric acid converts it into a variety soluble in cold water, and finally into dextrin. Hot nitric acid oxidises it to oxalic acid, $C_{24}H_{20}O_{20}+12(HO,NO_5)=12(HO,C_2O_{3\rightarrow})+20HO\rightarrow+12NO_2\uparrow$. Iodine and bromine combine with starch, and it, on the other hand, forms *amylates* with baryta, lime, and oxide of lead. It is insoluble in a solution of ammoniated copper, and is destroyed by strong alkalies.

Dextrin, $C_{24}H_{20}O_{20}$.

Prep.—(1) By boiling starch with dilute acids, ceasing when the liquid no longer reacts with iodine. (2) By the action of saliva or of *diastase,* a nitrogenous principle existing in germinating seed, at about 80° F. The process should be arrested by heating to the boiling-point, when the iodine reaction ceases; otherwise the dextrin is converted into grape sugar. One part of diastase will convert 2000 of starch into dextrin, or sugar. (3) *British gum,* which is identical with dextrin,* is prepared by roasting starch at about 400°, or by heating to 220° 500 of starch, 150 of water, and 1 of nitric acid for two hours. In all these cases the action of the acid is *catalytic,* it is itself unchanged. Dextrin has a sweetish taste, is very adhesive, and is used in coating labels, envelopes, etc. It does not ferment.

388. **Gum Arabic,** *Acacia, Arabin,* $C_{24}H_{22}O_{22}$, or $C_{12}H_{11}O_{11}$. Forms a viscid mucilage with water; by dilute acids it is converted into grape sugar. Nitric acid converts it into mucic acid, $C_{14}H_8O_{14},2HO$; it is precipitated by the subacetate of lead, forming a definite compound with the oxide of lead, $PbO,C_{12}H_{11}O_{11}$. Besides *Arabin,* Acacia contains lime.

389. **Gum Tragacanth,** *Tragacantha,* $C_{24}H_{20}O_{20}$, or $C_{12}H_{10}O_{10}$.—Consists almost wholly of *bassorin.* It swells with water to a bulky mass, which when long boiled acquires the general properties of *Arabin.* It is chiefly used in making paste. The gum of the cherry, plum, and apricot tree appears to be a mixture of Arabin and bassorin. The mucilage of quince-seed, flaxseed, elm, and marshmallow closely resemble the gums.

390. **Pectin,** $C_{64}H_{40}O_{56},8HO$.—The well-known property of gelatinising possessed by the juice of fruits, as currants, raspberries, etc., is due to Pectin. In the unripe fruit, *pectose,* a substance insoluble in water, alcohol, and ether, exists; during ripening, this is converted in great part into

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* GMELIN, *Handbook Cav. Ed.,* vol. xv. p. 187.

pectin; the change is accelerated by boiling; it is brought about by a sort of fermentation or catalytic change due to the action of the acids present in the fruit favoured by warmth and light. *Parapeptin* and *Metapeptin* are modifications; by the action of weak alkaline solutions, these are changed into pectic acid, $2HO,C_{32}H_{20}O_{28}$, which may be further converted into meta and para-pectic acids.

391. **Cane Sugar,** *Saccharum*, $C_{24}H_{22}O_{22}$.

Sources.—The sugar-cane, sorghum, beet-root, the ascending sap of the maple, corn-stalks; is also found in the date and cocoa palm, melons, bananas, pineapple, nectaries, of flowers, etc.

Prep.—The expressed juice is heated to coagulate albuminous matter, which is skimmed off, lime is added to neutralise acids which would convert it into fruit sugar (molasses); the juice is evaporated under diminished pressure. The raw or brown sugar thus obtained is refined; it is dissolved in lime-water, filtered first through woollen bags and then through animal charcoal. The solution, evaporated and crystallised, gives *loaf-sugar*, or, in large, oblique rhombic crystals (4th system), *rock-candy.*

Prop.—A sweet substance, s. g 1·6, soluble in $\frac{1}{3}$ its weight of water, at 60° forming syrup; boiling absolute alcohol dissolves $\frac{1}{80}$ of its weight, which deposits on cooling; commercial alcohol dissolves a larger proportion. Heated a little above 320° F., it cools to an amorphous mass,—*barley sugar, candy;* above 378°, loses 4 eq. water, becoming *caramel* or *burned sugar*, used for colouring liquids and syrups. It combines with lime and other bases, forming definite crystallisable salts, the formula of the lead salt at 212° being $4PbO,C_{24}H_{18}O_{18}$; it is probable that the rational formula of cane sugar is $4HO,C_{24}H_{18}O_{18}$. It also forms compounds with salts, as common salt, which are deliquescent and crystallise with difficulty. Strong sulphuric acid chars it; the dilute acids generally, and diastase, convert it into fruit sugar; nitric acid forms oxalic acid (see STARCH). The changes produced by fermentation will be considered hereafter.

392. **Fruit Sugar,** $C_{24}H_{24}O_{24}$. Occurs in the juice of ripe acid and subacid fruits, the descending sap of the maple, honey, etc. Is frequently associated in these with cane-sugar, which is converted into it by the action of dilute acids and diastase. It is very sweet, soluble, and uncrystallisable. It passes readily into grape sugar. Molasses, *Syrupus fuscus*, is fruit sugar, containing a considerable quantity of cane sugar in suspension. *Glycogen*, a starch-like substance obtained from the liver, has the same composition.

393. **Grape Sugar,** *Glucose*, $C_{24}H_{28}O_{28}$.—Forms the white crystals on the outside of dried fruits; exists in diabetic urine, normally in the liver, and is readily formed by the action of dilute acids upon starch, gum, and the other sugars.

Prop.—In warty imperfectly crystallised grains, less sweet than cane sugar in the proportion of 2 to 5; it is also less soluble in water, requiring one and a half times its weight, but is more soluble in alcohol. By the action of heat at 140° F., loses 4 equivalents of water and is converted into a body isomeric with fruit sugar; at a higher temperature forms caramel. Sulphuric acid combines with it to form *Sulphosaccharic* acid, the lime and baryta salts of which are soluble. Nitric acid converts it into oxalic acid. It forms certain unstable compounds with bases; is decomposed by strong alkalies. The tests for glucose will be considered under URINE. Its rational formula is probably $4HO,C_{24}H_{24}O_{24}$.

394. **Milk Sugar,** $C_{24}H_{22}O_{22}$, or $C_{12}H_{11}O_{11}$.—Is obtained by evaporating the whey of milk.

Prop.—In hard, gritty crystals, (3d system), soluble in 7 parts of cold water, insoluble in alcohol and ether. Is converted into glucose by dilute acids; nitric acid forms oxalic and mucic acids; it forms a hydrate $2HO,C_{24}H_{22}O_{22}$, and readily undergoes the *lactic* fermentation. Other sugars, or *quasi* sugars, as Mannite $C_{12}H_{14}O_{12}$, Glycyrrhizin $C_{36}H_{24}O_{14}$, *Quercite*, *Pinite*, *Sorbin*, *Mycose*, etc., are described. *Inosite*, sugar of flesh, *Glycocoll*, sugar of gelatine, and *Glycerine*, the sweet principle of fats, are not true sugars; they will be described hereafter.

395. **Glucosides.**—This term is applied to bodies which by boiling with dilute mineral acids, or aqueous alkalies, or by certain ferments, split up into glucose and one or more other compounds. They occur in both the vegetable and animal kingdoms, have never been produced synthetically, and are very numerous. The following are familiar examples: Gallo-tannic acid, yielding glucose and gallic acid, $C_{14}H_6O_{10}$; Salicin into glucose and saligenin, $C_{14}H_8O_4$; Scammony resin into glucose and scammonolic acid, $C_{32}H_{30}O_6$; Amygdalin into glucose, oil of bitter almonds, $C_{14}H_6O_2$, and hydrocyanic acid, HCy.

396. **Fermentation.**—Certain decomposing bodies—*ferments*—have the power of inducing decomposition in those with which they may, under favourable circumstances, be placed in contact. A very minute portion of a ferment is sufficient to set up the action, which then proceeds with more or less rapidity, producing, in the presence of compounds of ammonia and the phosphates, a much larger quantity of the ferment among the products of the change. The following circumstances are essential in all varieties of fermentation: (1) Contact of the ferment; (2) Presence of air; this is not essential after fermentation has once begun; (3) A temperature not below the freezing nor above the boiling point of water. It is retarded by too

high or too low a temperature between the limits named, and may be arrested by filtration, temperature, and antiseptics. The atmosphere contains always certain germs which have the power of inducing fermentation; these are destroyed by boiling, etc., and arrested by filtering the air through cotton. The forms of diseases grouped under the title of *zymotic*, are supposed to be due to the action of ferments; hence the use of the sulphites, carbolic acid, etc. as prophylactics and remedies.

The most important varieties of fermentation are the *vinous*, the *acetic*, the *lactic*, the *butyric*, and the *viscous*.

397. **Vinous Fermentation.**—The varieties of sugar which are truly fermentable appear to be the fruit and grape sugars, the other members of the group being converted into these by the action of chemical agents. The circumstances most favourable to the action are a temperature of 68–70° F., a weak solution of the sugar, say 10 p. c., and a proper proportion of the ferment. *Yeast* is composed of vegetable egg-shaped cells, which increase by budding during the fermentation of other than pure saccharine solutions; this increase in brewing may amount to $\frac{1}{4}$ the original weight; it generally rises to the surface, but when the process takes place at a low temperature, sinks. Other nitrogenised bodies, as albumen, casein, etc., will induce fermentation and the formation of yeast. During fermentation the following changes are noticed: (1) The evolution of CO_2, causing frothing, which begins at the sides of the vessel, and after a time covers its whole surface; (2) An agreeable, vinous odour; (3) A gradual diminution of the sweetness and s. g. of the liquid, and evidence of the presence of alcohol. The decomposition is never complete; a certain portion of unconvertible dextrin, saccharine matter, and other bodies remain. The chemical change taking place is the splitting up of the sugar into the simpler forms

of water, carbonic acid, and alcohol ($C_4H_6O_2$). Thus grape sugar, $C_{24}H_{28}O_{28}=8CO_2+4(C_4H_6O_2)+4HO$; it yields 46·46 p. c. of alcohol; fruit sugar yields 51·12 p. c., and cane sugar 53·22 p. c., supposing the fermentation to be complete. We may arrest the process by filtration to remove yeast, boiling or freezing, or by antiseptics, of which carbolic acid, sulphurous acid, or the sulphites, are practically the best.

Processes depending upon Fermentation.—*Bread-Making.* When flour is mixed with water, the *gluten* makes a tough paste, *dough.* The yeast added causes a portion of the starch to ferment; after becoming sugar, the carbonic acid given off swells up the pasty dough, and the bread is *raised.* The carbonic acid and alcohol formed are driven off during the baking. By Dauglish's process the flour is impregnated with CO_2, under pressure, no fermentation being allowed; thus a portion of the starch is saved, and a purer and more palatable bread obtained.

Wines.—The generic term *wine* may be applied to the fermented juice of fruits. We may distinguish Grape wine, wine proper; that from currants, gooseberries, etc., Domestic wines; Cider from apples, Perry from pears, etc.

The juice of grapes exposed to the air ferments, owing to the presence of albuminous matters in the pulp; it is then put into casks. A second fermentation takes place in the succeeding spring, after which its impurities subside. The quantity of alcohol gradually increases, owing to the further change of the sugar, and the cream of tartar existing in grape juice is deposited as *argols;* thus true wine improves up to a certain point by age; beyond this, it again becomes acid or *pricked* from the formation of acetic acid. Sparkling wines are bottled before the second fermentation, and contain the CO_2, due to it. Domestic wines contain malic acid, which does not deposit; hence they are sour, unless this acid is disguised by sugar; generally a considerable quantity of spirits is added to make them keep. They cannot compare in wholesomeness with the wine of grapes. The varying properties of wines depend upon the percentage of alcohol and sugar. The former may be determined by distilling off one-half of the wine, diluting the distillate with water enough to make up the original bulk, and testing with the hydrometer (17); the latter by evaporation. The following is a general average statement. Port, Madeira, and Sherry contain 20 p. c.; Hock, Claret, and Champagne, 11 p. c., and domestic wines 10 to 20 p. c., of alcohol. The quantity of sugar is least in the Hocks, and greatest in the syrupy wines, as some kinds of Port, Angelica, Malmsley, etc. The acidity of true wines is due to cream of tartar; if the grapes were green, citric acid may be present, and in old wines acetic acid. Cider contains lactic acid. Moselle and Rhine wine are the most acid, Port and Sherry the least so. Tannic acid imparts roughness or astringency to wines, and prevents their becoming *ropy* (viscous fermentation). Wine casks are fumigated with SO_2, to prevent their contents from souring (acetic fermentation). Wine is officinal as *Vinum Portense*, Port Wine, and *Vinum Xericum*, Sherry.

Beer.—In brewing, a *mash* is made of *malt*, barley, which has been allowed to germinate after steeping in water, by which its starch is converted into dextrin and sugar; to this mash yeast is cautiously added, and fermentation allowed to take place to a certain point, leaving a considerable proportion of unchanged dextrin and sugar. To the *worts* thus obtained is added an infusion or decoction of hops, by which a bitter flavour is given and fermentation checked. A slow fermentation goes on after the beer is barrelled, and causes the liquid to be charged with CO_2.

In the brewing of *lager*, the fermentation is conducted at a low temperature, 33° to 46½° F. The yeast sinks to the bottom, carrying much albuminous and gummy matter, and leaving a very clear beer. It is put in casks coated inside with resin, and stored for a long time before using. The amount of alcohol in beer varies from 2 p. c. in some kinds of lager and small beer to 8 in XXX ale and brown stout. The high colour of porter and stout is due to the use of malt which has been slightly charred in the *kiln*, used for checking the germination of the malt.

SPIRITS are distilled from fermented liquids; Brandy, *Spiritus Vini Gallici*, from wine; Whiskey, *Spiritus Frumenti*, from a mash of corn or rye; Rum, from the juice of the sugar cane, or from molasses, etc. They contain about 50 p. c. of absolute alcohol, by volume, when at *proof*. Their strength can be ascertained directly by the hydrometer. They all improve by age when kept in wood, owing to the oxidation of injurious bodies, known as fusel oils, to fragrant and harmless ethers. The presence of fusel oil is disguised by sugar and mucilages, and it may be removed by filtering through charcoal mixed with MnO_2.

398. *Acetous Fermentation.*—A weak solution of alcohol, exposed to the air in contact with a ferment, absorbs oxygen and becomes acid. This change will be studied under the head of ACETIC ACID.

399. *Lactic Fermentation.*—Sugar of milk, under the influence of the casein present in that fluid, or by the contact of certain animal membranes (rennet), ferments, *lactic acid* being formed. This is the cause of the souring of milk. It may be retarded by boiling, and prevented by boiling under a pressure of 1·5 atmospheres (Pasteur), or by evaporating the milk to a solid form (condensed milk). Lactic acid may also be produced from cane fruit or grape

sugar, by mixing with stale milk, putrid cheese, and chalk. Lactate of lime is formed abundantly.

Lactic acid, *Acidum lacticum*, $HO,C_6H_5O_5$, has an intensely sour taste and acid reaction; it forms well-marked salts, of which that of FeO is officinal, *Ferri Lactas.* It exists in the gastric juice, the juice of flesh, in *Sauerkraut*, and in the albuminous liquid left in the manufacture of starch. It has been used in the free state and as lactate of soda in dyspepsia.

400. *Butyric Fermentation.*—By a continuance of the fermentation of the mixture described above, the lactic acid passes into *butyric*, an acid found in rancid butter, putrid flesh, etc.; $2(HO,C_6H_5O_5)=HO,C_8H_7O_3+4CO_2+H_4$. Its properties will be considered in the next group (413).

401. *Viscous Fermentation.*—The sugar of the beet at about 100° undergoes a peculiar change. But little alcohol is formed, the products being lactic and butyric acids, mannite and gum; CO_2 and H are given off. Ordinary sugar undergoes this change to a certain extent when treated as directed for obtaining lactic and butyric acid. The ropiness of wines and beer present examples of it.

402. THEORIES.—The phenomena of fermentation and putrefaction were attributed by Berzelius to catalysis (159). Liebig supposes that the change taking place in the molecules of the ferment is communicated to those of the solution in which it is placed, a process which he terms decomposition by *example* (160). These merely give a name to the change, but do not explain it. Schwann, Blondeau, and Schmidt referred them to the unexplained action of microscopic plants and animals; which view received support from experiments in supplying fermentable matter with air drawn through cotton or a red-hot tube, in which case the change did not take place.*

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* GMELIN, *Handbook Cav. Ed.*, vol. vii. p. 108.

Pasteur comes to the following conclusions, which are probably nearest the truth. No fermentation or putrefaction occurs without the generation of multitudes of low animal or vegetable (?) organisms, known to the microscopists as *mycoderms*, *torulas*, *vibrios*, *bacteriums*, *monads*, etc. Some of these, as the vibrios, live only in an atmosphere deprived of oxygen; others, as the bacteriums and monads, absorb oxygen. Each variety of fermentation has an organism peculiar to itself; thus the *mycoderma vini* causes sugar to break up into alcohol and carbonic acid; the *mycoderma aceti*, mother of vinegar, serves to oxidise alcohol to acetic acid, and the latter, in the absence of alcohol, to water and carbonic acid; *pencillium glaucum* converts sugar into lactic acid. Butyric fermentation and animal putrefaction are due to the combined action of the bacteriums and monads, which absorb oxygen, and of the vibrios, which act in the interior of the liquid away from oxygen. The phenomena vary according as the body is freely exposed to the air, or partially or wholly secluded. They are instantly arrested by a temperature of 130°, or by the action of antizymotics, as sulphurous acid, the sulphites, carbolic acid, etc.

II. RADICALS OF THE GENERAL FORMULA C_2nH_2n+1.

403. THEORETICAL CONSIDERATIONS.—The hypothesis of the existence of compound bodies which act as elements —*quasi* elementary bodies, *radicals*—is exceedingly convenient. In inorganic chemistry we have already had ex-

amples of a perfect quasi metal, ammonium, NH_4, and of a quasi halogen, cyanogen, C_2N. Without discussing the arguments in favour or opposed to such a view, it may be stated that it brings a large number of organic compounds under the same type as those generally regarded as inorganic, and is at least as probably true as any other which has been suggested. As we know nothing of the arrangement of the elements in compounds, that theory is preferable which is the most simple. The great majority of the radicals contain C and H only, and the atoms of C are even, those of H odd. The protoxide of a radical is generally termed its *ether* (although the word is also applied to the compounds of acids with this oxide); its hydrated oxide, the *alcohol* of the series. The quasi metallic radicals may be divided into those which form a single basic protoxide, like zinc, as the *ethyl* type, *positive radicals*; and those which tend to form higher acid oxides, like Cr,—the *acetyl* type, *negative radicals*. Generally speaking, the compounds of the former and the radicals themselves are obtained from their alcohols, which act with acids and halogens like the hydrates of the metallic oxides. The alcohols and ethers by oxidation yield the oxides of the negative radicals. The following are the most important members of the series; others, especially among the acids, will be incidentally considered under other heads.

	+Radical.	Ether.	Alcohol.
Formula..........	$C_2nH_2n+_1$	$C_2nH_2n+_1,O$	$C_2nH_2n+_1,O,HO$
Methyl,	C_2H_3	C_2H_3O	C_2H_3O,HO
Ethyl,	C_4H_5	C_4H_5O	C_4H_5O,HO
Propyl,	C_6H_7	C_6H_7O	C_6H_7O,HO
Butyl,	C_8H_9	C_8H_9O	C_8H_9O,HO
Amyl,	$C_{10}H_{11}$	$C_{10}H_{11}O$	$C_{10}H_{11}O,HO$

—Radical.	Aldehyde.	Acid.
$C_{2n}H_{2n-1}$	$C_{2n}H_{2n-1},O,HO$	$C_{2n}H_{2n-1},O_3,HO$
C_2H Formyl,	C_2HO,HO	C_2HO_3,HO Formic.
C_4H_3 Acetyl,	C_4H_3O,HO	$C_4H_3O_3,HO$ Acetic.
C_6H_5 Allyl,	C_6H_5O,HO	$C_6H_5O_3,HO$ Propionic.
C_8H_7 Butyryl,	C_8H_7O,HO	$C_8H_7O_3,HO$ Butyric.
$C_{10}H_9$ Valyryl,	$C_{10}H_9O,HO$	$C_{10}H_9O_3,HO$ Valerianic.

As an illustration of the changes taking place, we may take the ethyl series. *Alcohol*, C_4H_5O,HO, by losing water, becomes C_4H_5O, *Ether*. By the action of iodide of phosphorus, C_4H_5I, iodide of ethyl, is formed; by digesting this with zinc, *ethyl* is obtained, $C_4H_5I + Zn = ZnI + C_4H_5$. By the action of HO,NO_5 (with urea) on alcohol, *nitrate of ether* is formed, $C_4H_5O,HO + HO,NO_5 = C_4H_5O,NO_5 + 2HO$. By oxidation, alcohol first loses two of hydrogen and becomes *aldehyde*, $C_4H_5O,HO + O_2 = C_4H_3O,HO + 2HO$, and finally *acetic acid*, $C_4H_5O,HO + O_4 = C_4H_3O_3,HO + 4HO$. These are but types of the reactions occurring in the whole series. All the alcohols above named have been isolated; the aldehydes are not yet complete. The list of acids might be continued uninterruptedly up to $C_{36}H_{35}O_3,HO$, Stearic; and with interruptions to $C_{60}H_{59}O_3,HO$, Mellisic acid. These acids are generally known as the fatty acids. Their boiling-point rises about 35·88° F. for each increase of C_2H_2. The whole series is homologous. Only the more important members of the series will be considered.

405. **Methyl Alcohol,** *Wood Spirit,* C_2H_3O,HO.—Is among the products of the destructive distillation of wood. Is a colourless, inflammable, mobile liquid, miscible in all proportions with water and alcohol, s. g. 0·798, boils at 152°, has a peculiar odour and taste. Its solvent powers resemble those of alcohol. Methylated spirit contains 10 p. c., and may be used for most purposes as a substitute for alcohol. Wood spirit is often confounded with acetone, $C_6H_6O_2$, obtained by distilling the acetates. It has been used as a stimulant expectorant in Phthisis.

406. **Formic Acid,** HO,C_2HO_3.—Exists in ants, certain caterpillars, nettles, and the sweat. May be made by direct oxidation by the action of platinum black on wood spirit.

Is preferably prepared by the decomposition of oxalic acid, by heat, in the presence of glycerine; the latter remains unchanged. The proportions are not important; the mixture is heated until CO_2 is evolved, when more HO, C_2O_3 is added until no more CO_2 is given off; formic acid distils over. $2(HO,C_2O_3+2HO)=HO,C_2HO_3+4HO+2CO_2$. It may also be obtained by distilling red ants with water. The monohydrated acid is obtained by the action of HS upon PbO,C_2HO_3. It resembles its homologue glacial acetic acid; it is very corrosive, blisters the skin, s. g. 1·235, boils at 209°; mixes with water and alcohol in all proportions. Its vapour is inflammable. It reduces the salts of silver and gold.

Berthelot has made formic acid by the action of CO upon KO, HO, $2CO+KO,HO=KO,C_2HO_3$: an interesting example of a body originally derived from the animal kingdom obtained from purely animal sources. By destructive distillation the formates yield compounds of carbon and hydrogen of a more complex nature.

407. **Chloroform,** *Chloroforum,* C_2H,Cl_3.—May be regarded as the terchloride of formyl, or formic acid, in which O_3 have been replaced by Cl_3.

Prep.—On the large scale, distilling chloride of lime, $CaO,ClO+CaCl$, with alcohol, wood spirit, or acetone,—*Chloroformum venale.* It is used in this state as a solvent. *Chloroformum purificatum* is prepared by agitating occasionally for 24 hours ℥cii *Chloroformi venalis* and ℥xvii *Acid. Sulphuric.*, then separating the lighter chloroform and adding to it fʒvj *Alcohol. fortioris* and ℥ij *Potass. Carb.* previously heated to redness and rubbed to powder; the mixture is then stirred thoroughly and distilled.

Prop.—A limpid, colourless, volatile, neuter liquid, of an agreeable, ethereal odour, and a sweetish, burning taste. Water dissolves but one p. c; Alcohol dissolves it freely. It dissolves caoutchouc, gutta-percha, the resins, camphor, iodine, bromine, and most of the alkaloids. It is not inflammable. Its s. g. is 1·490 to 1·494; it boils at 140°. When dropped into water, it should sink without milkiness (absence of oils). Mixed with an equal weight of HO,SO_3, no sensation of warmth should be communicated to the hand by the containing vessel, and after standing 24 hours, the acid should have but a faint, yellow tinge (absence of water, alcohol, and oils). A small portion being evaporated from a porcelain plate, the last portions should have a faint, aromatic odour, without pungency or empyreuma, while the plate is covered with a film of moisture free from smell or taste (absence of oils and free Cl). It does not affect a solution of AgO,NO_5 (absence of free Cl). Its uses are too well known to be detailed. It is employed in the *Linimentum Chloroformi*, the *Mistura Chloroformi*, and in the *Liquor Guttæ-Perchæ.* Similar compounds with Br and I — C_2H,Br_3 and C_2HI_3 — are known.

408. **Ethyl Alcohol;** *Alcohol,* C_4H_5O,HO.

Prep.—By the distillation of liquids which have undergone the vinous fermentation. Synthetically, by prolonged agitation of olefiant gas, mercury, and sulphuric acid. $C_4H_4+2(HO,SO_3)=C_4H_5O,HO,2SO_3$, Sulphovinic acid; $C_4H_5O,HO,2SO_3+2HO=C_4H_5O,HO+2(HO,SO_3)$. This process has been tried upon the large scale, but was not successful in an economical point of view. Although alcohol boils at 172°, yet, owing to the adhesion between its vapour and that of water, and the evaporation of the latter, they always distil over together. To obtain alcohol free from water, it must be redistilled with fused chloride of calcium and excess of lime; it then forms *absolute* alcohol.

Prop.—Absolute alcohol is a colourless, transparent, volatile liquid, boiling at 172°, not frozen at any known temperature, inflammable, s. g. 0·7938. It has a slight, agreeable odour, distinct from that of ordinary alcohol. It attracts water, and when the two are mixed, the bulk of the resulting liquid is less than that of its components, while an elevation of temperature is noticed. The absence of water may be shown by introducing a bit of anhydrous baryta, which will fall to pieces if water be present. Alcohol is officinal as *Alcohol. fortioris*, s. g. 0.817, which contains 92 p. c. of alcohol; *Alcohol*, s. g. 835, 85 p. c.; and *Alcohol dilutum*, proof spirit, made by diluting alcohol with an equal measure of water, s. g. 0·941, 39 p. c.

The term *proof spirit* was applied originally to alcohol strong enough to set fire to gunpowder when lighted. If 100 vols. of a spirit require 10 vols. of water to bring it to proof, it is said to be 10 over proof; if it require 10 vols. of spirit, s. g. 825, to raise it to proof, it is said to be 10 under proof. The strength of proof spirit varies in different localities, and it would be well if so ambiguous a designation were no longer used. The officinal *alcohol dilutum* is *below* the proof spirit of England and most of the United States.

Alcohol has a stronger odour than the absolute, and contains fusel oils, which may be removed by filtering through charcoal, distilling over soap or permanganate of potassa (Attwood's patent). The solvent powers of alcohol are considerable; it dissolves sulphur and phosphorus in small quantity, iodine and ammonia freely; caustic potassa, soda, and lithia; most of the alkaloids, tannic acid, grape sugar, camphor, resins, balsams, volatile oils, soap; the fixed oils sparingly, except castor oil, which is abundantly soluble in stronger alcohol. Most acids and their salts give with it, on distillation, their characteristic ethers. All deliquescent salts, except carbonate of potassa, most of the soluble chlorides, and some nitrates, are soluble in alcohol; all efflorescent salts, those insoluble, or sparingly soluble in water, and the metallic sulphates, are insoluble. Solutions in alcohol are called *Tinctures*, or *Spirits*.

The uses of alcohol are well known; the officinal preparations into which it enters are numerous. Whiskey, brandy, port and sherry wines are officinal (397). When burned, alcohol yields HO and CO_2; slowly oxidised, it furnishes aldehyde and acetic acid.

409. *Ether*, Wine ether, Sulphuric ether, C_4H_5O.

Prep.—By the action of HO,SO_3 upon alcohol. The products depend upon the temperature at which the mixture boils, which, in turn, depends upon the relative proportions of its constituents. Below 260°, alcohol distils unchanged; between 260° and 310°, ether comes over with some alcohol and water; above 320°, the mixture chars; oil of wine, $C_4H_4,SO_3+C_4H_5O,SO_3$, olefiant gas, C_4H_4, and other products are obtained. By the *continuous* ether process, a mixture is made in such proportions as to boil at about 286°, and fresh alcohol is constantly supplied so as to maintain that temperature. The sulphuric acid undergoes no change, and may be used for the conversion of an indefinite quantity of alcohol into ether. The theory is not well understood. It is certain that alcohol, C_4H_5O,HO, under the influence of the HO,SO_3, splits up into C_4H_5O and HO, but why is not yet ascertained. It is generally supposed that *sulphovinic* acid, $C_4H_5O,HO,2SO_3$, is formed and again decomposed; $C_4H_5O,HO,2SO_3+2HO=C_4H_5O+HO+2(HO,SO_3)$. The ether and water which distil over form distinct layers, and are easily separated. The ether is then agitated with KO, CO_2, and redistilled, forming the officinal *Æther*. This yet contains alcohol and water, to remove which it is shaken with water to remove alcohol, then mixed with fused CaCl and quicklime, allowed to stand twenty-four hours (to remove water) and redistilled. *Æther fortior*, washed ether, letheon.

Prop.—Pure ether is a colourless liquid, of a peculiar, pleasant odour, boiling at 98°, not frozen as yet, s. g. 0·713, producing from its volatility cold by evaporation; it is very inflammable, and its vapour mixed with air explodes. Is soluble in 10 parts water, or will take up $\frac{1}{10}$ of that liquid. When held in the hand, it will boil violently, if a fragment of glass be dropped into it. On evaporation, it should leave no empyreumatic odour, but only a film of tasteless moisture. It dissolves fats and oils; also I, Br, P, HgCl, and most of the alkaloids. Is used as an anæsthetic and diffusible stimulant; externally, its spray is used to produce local anæsthesia (195).

410. *Spiritus Ætheris Compositus*, Hoffman's Anodyne.

Prep.—℞. *Ætheris* Oj, *Alcohol* Oj, *Olei Ætherei* f℥vj. M. The ethereal oil *Oleum Æthereum*, heavy oil of wine, is obtained by distilling alcohol and sulphuric acid at a temperature between 312° to 322°; it is diluted with an equal measure of washed ether. It is regarded as a double sulphate of ether and ethylene, $C_4H_5O,SO_3+C_4H_4SO_3$. It is a heavy oil, sinking in water, in which it sparingly dissolves; it does not precipitate with baryta, but forms a soluble sulphovinate of that base.

Prop.—But little true Hoffman's Anodyne is found in the shops. It is sometimes adulterated with fixed oils. It should give no precipitate with BaCl, or only a slight cloudiness (absence of HO,SO_3). When a few drops are burned on a glass or porcelain plate, there is no visible residue, but the surface will be left with an acid taste and reaction. A pint of water is rendered slightly opalescent upon the addition of 40 drops. It is a popular stimulant and antispasmodic.

411. *Spiritus Ætheris Nitrosi*, Sweet Spirit of Nitre.

Prep.—By distilling *Acid. Nitric.* and *Alcohol* in excess, and redistilling over carbonate of potassa. It is a solution of 4·3 to 5 p. c. of nitrite of ether, C_4H_5O,NO_3, in alcohol. Pure nitrite of ether is a yellowish liquid, of an agreeable smell like apples, s. g. 0·947, and boiling at 62°.

Prop.—A colourless volatile liquid, of a fragrant, ethereal odour; boils at 145°; s. g. 0·837. Becomes acid when kept in badly stoppered bottles, acetic acid being formed. It may also contain *aldehyde;* this gives a brown colour when mixed with solution of potassa. The presence of any acid in excess is shown by its action on litmus and by the usual tests. It is often adulterated by mere dilution with alcohol and water.

Other Compounds of Ether.—The Nitrate, Sulphate, and Sulphite have been obtained. The acetate of ether (acetic ether), and chloride of ethyl, C_4H_5Cl (muriatic ether), are sometimes used in medicine. The iodide of ethyl is much used in chemical research; the bromide and cyanide are also known; in fact, the entire series of compounds of ethyl with the amphigens and halogens, and of ether with the acids, is nearly complete.

412. **Acetic Acid**, $HO,C_4H_3O_3$.

May be formed, (1) By the direct oxidation of alcohol; (2) by the oxidation of alcohol by means of a ferment; (3) by the distillation of wood. It exists in the sweat and some other secretions.

1. Platinum black possesses the power of directly oxidising alcohol, being itself unchanged. This plan has been tried in the manufacture of vinegar (Dobereiner's process), but is not economical on account of the high first cost of platinum black.

2. Weak (not over 10 p. c.) alcohol, such as stale beer, cider, wine, etc., mixed with a ferment (vinegar is the best), and exposed to a somewhat elevated temperature, 74° to 86°, absorbs oxygen, and gradually becomes acetic acid. The stronger the alcoholic solution, the slower the

process; under favourable circumstances it is complete in from 4 to 6 weeks. The process is often accompanied by the development of a plant, the *mycoderma aceti*, or *mother of vinegar*. Frequently flies, *muscæ cellaris*, and eels, *vibriones aceti*, are found; and if made of weak alcohol, it will sometimes undergo a sort of viscous or putrefactive fermentation. This is prevented by adding a little alcohol after the change is complete (402).

In the *quick* vinegar process, the "wash" or weak alcohol is passed through beech shavings or powdered charcoal moistened with vinegar, air being freely supplied. A perceptible elevation of temperature is noticed, fusel oils are oxidised into ethers, and the process is complete in a day. On the large scale, common whiskey is used.

3. During the distillation of wood, especially the harder varieties, a large quantity of acetic acid is formed which is charged with tarry matters, crude *pyroligneous acid.* By saturating this with lime, the tarry matters are left, and by decomposition with HO,SO_3, the acetic acid is obtained.

Monohydrated acetic acid, glacial acetic acid, ice vinegar, may be procured by distilling 83 parts by weight of fused acetate of soda and 100 of HO,SO_3. It is a volatile, inflammable liquid, boiling at 248°, and solid at 40°. It blisters the skin, and is soluble in water, alcohol, and ether; dissolves camphor, the volatile oils, and several resins. The anhydrous acid has been obtained. Acetic acid is officinal as *Acetum, Acetum destillatum, Acidum aceticum*, and *Acidum Aceticum dilutum.* The *Aceta Colcheci, Lobeliæ, Opii, Sanguinariæ, Scillæ*, are also officinal.

Acetum, Vinegar.—Impure dilute acetic acid, obtained by fermentation.

Prop.—A well-known liquid, of an agreeable, acid smell and taste. It contains, besides acetic acid and water, gum, sugar, gluten, sulphates, and often tartaric and malic acids. Sulphuric acid is detected by boiling with $CaCl$, ($BaCl$ would be decomposed by sulphates existing normally), HCl by AgO,NO_5, and injurious metals by HS. A fluidounce is saturated by not less than gr xxxv *Potass. bicarb.*, and after saturation the liquid is free from acrid taste.

Acetum destillatum, made by distilling from Oviii *Aceti* to Ovij. It contains a little aldehyde. It is wholly volatilised by heat, and is not affected by the tests for the metals generally. It is of about the same strength as *Acid. acetic. dilut.*; 100 grains should saturate not less than 7·6 grs *Potass. bicarb.* (5 p. c. of $HO,C_4H_3O_3$).

Acidum Aceticum.—Acetic acid, s. g. 1·047.

Prop.—A colourless liquid, having a pungent odour; is wholly volatilised by heat, and not affected by the tests for HO,SO_3, HCl, or the metals. One hundred grains saturate gr lx *Potass. bicarb.*, and contain gr xxvi $HO,C_4H_3O_3$. A convenient method of determining the strength of vinegar is to suspend in it a weighed fragment of pure marble; when action has ceased, wash, dry, and weigh it. The loss will be five-sixths of the $HO,C_4H_3O_3$ present; $CaO,CO_2=50$; $HO,C_4H_3O_3=60$.

Acidum Aceticum dilutum.—℞. *Acid. Acetic.* Oj, *Aquæ Destillatæ* Ovii, M.; s. g. 1·006. 100 grs saturate 7·6 grs. *Potass. bicarb.* It contains 5 p. c. of monohydrated acid.

413. **Butyric Acid**, $HO,C_8H_7O_3$.

Prep.—By the butyric fermentation (401). Exists free in putrid flesh, sweat of the feet, armpits, etc.; privies, *sauerkraut*, Limburger cheese, etc.; and combined in butter and cheese.

Prop.—Is an offensive, inflammable liquid, boiling at 157°, and solid at —133°. The butyrate of ether, butyric ether, $C_4H_5O,C_8H_7O_3$, when diluted, has the odour of pineapples, and is used in making confectionery and factitious brandy.

414. **Amylic Alcohol**, *Alcohol Amylicum*, fusel oil, $C_{10}H_{11}O,HO$.

Prep.—By continuing the distillation of crude corn or potato whiskey, after the greater part of the alcohol has come over. The name is also applied by distillers to the light oils which come over at the beginning of the process.

Prop.—When pure, a colourless, oily liquid, of characteristic odour, producing much irritation of the fauces when inhaled, and poisonous; s. g. 0·818; boils at 269°, solid at —4°. Is sparingly soluble in water, freely so in alcohol and ether. It burns with difficulty, dissolves fats, resins, camphor, sulphur, and phosphorus.

Amylene, $C_{10}H_{10}$, has been used as an anæsthetic, but abandoned as dangerous.

415. **Valerianic Acid**, *Acidum Valerianicum*, $HO,C_{10}H_9O_3$.

Prep.—By oxidising fusel oil; generally, by the action of $KO,2CrO_3$ and HO,SO_3. Exists in valerian root and other vegetables; does not exist in the animal organism. The same is true generally of the acids of this group, the carbon of which is not divisible by 4.

Prop.—A colourless liquid, of an acrid, burning taste, boiling at 176°, and soluble in 26 parts water. The valerianates of soda, ammonia, zinc, and quinia are officinal, and that of morphia is much used. They are all antispasmodic. The acid is not given in the free state.

The acids *homologous* (384) with valerianic, and highe
the series, are numerous; some will be considere
the head of FATS. Caproic, $HO,C_{12}H_{11}O_3$; C
$C_{16}H_{15}O_3$; Capric, $HO,C_{20}H_{19}O_3$, accompan

the sweat, etc.; Pelargonic acid, combined with C_4H_5O, in the *bouquet* of wine, and in the quince; it may be made artificially by the oxidation of oil of rue.

Valerianate of the oxide of amyl, $C_{10}H_{11}O$, $C_{10}H_9O_3$, diluted, gives artificial apple essence; acetate of the same, $C_{10}H_{11}O$, $C_4H_3O_3$, the pear essence; coccinate of oxide of ethyl, C_4H_5O, $C_{26}H_{25}O_3$, the quince. Mixtures of these give various other *fruit essences.* Butyric ether has been before mentioned.

III. RADICALS NOT HOMOLOGOUS WITH ETHYL.

416. **Benzyl,** or **Benzoxyl,** $C_{14}H_{15}O_2$.—Has been isolated as a colourless, fragrant liquid.

Hydride of Benzyl, $C_{12}H_5O_2,H$, Oil of bitter almonds; *Oleum Amygdalæ amaræ.*

Prep.—By distilling the bitter almond with water. It does not pre-exist in the kernels, but results from a *quasi* fermentation of *Amygdalin,* $C_{40}H_{27}NO_{22}$, under the influence of a pulpy, albuminous substance, *Syneptase;* glucose and hydrocyanic acid being formed at the same time.

Prop.—The officinal (crude) oil has a yellowish colour, bitter, acrid, burning taste, and characteristic odour, s. g. 1·052 to 1·082. It contains HCy, and is sometimes prescribed as a sedative. As the proportion of this active ingredient is variable, bitter almond oil should never be employed. When used as a flavoring material for cakes, the HCy is driven off during the baking. The pure oil is colourless, s. g. 1·043, inflammable, soluble in 30 parts water, and freely in alcohol and ether; it is not poisonous. On exposure to the air it oxidises to benzoic acid.

417. **Benzoic Acid,** *Acidum Benzoicum,* $C_{14}H_5O_2,O,HO$, is the alcohol of the series; the anhydrous acid has been obtained.

Prep.—From the true *balsams*, generally by sublimation from gum benzoin; also by boiling the gum with lime, and precipitating the benzoic acid by HCl. Is also procured from the putrid urine of horses and cows, occurring here from the decomposition of *hippuric* acid.

Prop.—When obtained by sublimation, is in light, feathery, colourless crystals, having a faint, agreeable smell, melting a little below 212°, soluble in 200 parts cold and 25 of boiling water; its solubility may be increased by the addition of borax or phosphate of soda. It is freely soluble in alcohol. Benzoic acid is an ingredient in paregoric; it has been used in renal and vesical affections. The benzoates are all soluble. By distilling the benzoate of copper, an oil having the odour of the rose geranium is obtained, which is *Benzyl*, the radical of the series; by the action of KO,HO it is converted into benzoic acid. Among the products of the destructive distillation of benzoate of ammonia is *benzonitrile*, $C_{12}H_5C_2N$, which has exactly the odour of the bitter almond oil; it must not be confounded with nitrobenzol, $C_{12}H_5NO_4$, which has somewhat similar properties.

418. **Benzole,** $C_{12}H_6$.

Prep.—By distilling benzoic acid with lime, or in the more volatile portion of the oil obtained by distilling coal-tar. The *benzine* obtained from petroleum is a distinct body; it is used as a substitute for turpentine, and to dissolve grease, India-rubber, etc.

Prop.—A thin, limpid, colourless, inflammable liquid, s. g. 0·855, boils at 176°, solid at 32°. It may be regarded as the hydride of the radical Phenyl, $C_{12}H_5$, of which *benzonitrile* is the cyanide, $C_{12}H_5C_2N$. *Nitroben-*

zole, a substitution compound, $C_{12}\frac{H_5}{NO_4}$, and Phenic or carbolic acid, $C_{12}H_5O,HO$, the alcohol.

Nitrobenzole, *Essence of Mirbane,* $C_{12}H_5NO_4$.

Prep.—By the action of HO,NO_5 upon $C_{12}H_6$. Benzine from petroleum does not yield it.

Prop.—A heavy, yellowish, sweet liquid; s. g. 1·209; having an odour resembling somewhat that of bitter almonds, or the vernal grass. It boils at 415°, is insoluble in water. Is used in perfumery. Is highly poisonous, whether inhaled or swallowed; the symptoms in some cases not appearing for days after it has been taken (Letheby). Is converted by nascent hydrogen into *aniline*, $C_{12}H_5NO_4+H_6=NC_{12}H_7+4HO$, and is found as such in the tissues and secretions after death.

Phenic, or **Carbolic Acid,** $C_{12}H_5O,HO$.

Prep.—Is among the products of the distillation of coal-tar.

Prop.—When pure, a colourless, deliquescent, crystalline solid, having an odour like creasote, and a caustic taste. It fuses at 95°, and vaporises at 370°. Is used as a caustic and antiseptic. *Cresylic acid*, $C_{14}H_8O_2$, also obtained from coal-tar, resembles carbolic acid in its properties.

418. **Cinnamyl,** $C_{18}H_7O_2$.

Is the radical of a series of which the hydride $C_{18}H_7O_2$, H, Oil of Cinnamon, *Oleum Cinnamomi*, is the only member employed in medicine. Oil of cinnamon may be artificially prepared by the oxidation of *Styrone*, which is obtained by the distillation of storax with caustic potassa.

419. **Salicyl,** $C_{14}H_5O_4$.

Is the radical of a series of which the hydride is identical with the Oil of *Spiræa ulmaria*, or Meadow-sweet. is obtained from *Salicin* ($C_{26}H_{18}O_{14}$), a crystalline, bitter le, derived from the bark of the willow, poplar, etc.

Salicin may be artificially made by the action of caustic potassa upon the Oil of *Gaultheria procumbens*, *Oleum Gaultheriæ*. Salicin is employed as a substitute for quinia. *Phloridzin*, $C_{42}H_{24}O_{20}+4HO$, is an analogous substance found in the bark of the root of the cherry, apple, etc.

420. **Kakodyl**, $C_4H_6As=2(C_2H_3)As$, or Kd.

Forms a large series of compounds mostly of a highly offensive and poisonous character. The radical itself has been isolated as a thin, colourless liquid, and from it all the compounds may be directly formed, giving us the most perfect example of a *quasi* metal known. It may be regarded as a conjugate compound of two eq. of methyl and one of arsenic.

Oxide of Kakodyl, C_4H_6As,O, or KdO, Alkarsin, Fuming Liquor of Cadet.

Prep.—By distilling equal weights of acetate of potassa and arsenious acid. May be formed by the direct union of kakodyl with oxygen.

Prop.—A colourless, ethereal liquid, of a highly offensive smell, irritating the nose and eyes, and very poisonous. Boils at about 302°; s. g. 1·462. Takes fire spontaneously in the air, burning with a pale flame, producing carbonic acid, water, and arsenious acid.

From the oxide, the other members of the series may be formed. The chloride and cyanide are especially poisonous. Kakodylic acid, KdO_3, Alkargen, formed by the oxidation of Kd or KdO, is a solid, soluble in water and alcohol, and *not* poisonous.

IV. ORGANIC ACIDS.

Not oxides of known radicals, and not otherwise classified.

Tartaric,	$2HO,C_8H_4O_{10}$.
Racemic,	$2HO,C_8H_4O_{10}$.
Citric,	$3HO,C_{12}H_5O_{11}+HO$.
Malic,	$2HO, C_8H_4O_8$.
Tannic,	$3HO,C_{54}H_{19}O_{31}$.
Gallic,	$3HO,C_{14}H_3O_7$.
Pyrogallic,	$C_{12}H_6O_6$.
Metagallic,	$C_{12}H_4O_4$.

421. (*a*) **Tartaric Acid**, *Acidum Tartaricum*, $2HO,C_8H_4O_{10}$.

The acid of grapes, tamarinds, etc.; is obtained from the deposit in wine casks (Argols, Crude Tartar), which is impure Acid Tartrate (Bitartrate) of Potassa.

Prep.—By decomposing the acid tartrate of potassa, by carbonate of lime; and the resulting tartrate of lime, by sulphuric acid.

Prop.—Transparent, colourless crystals (4th system), containing two eq. of basic water. It is soluble in its weight of cold, and one-half its weight of boiling water. Forms tartrates, of which those of potassa, and the double salts of potassa and soda, of iron and potassa, and of antimony and potassa, are officinal.

Tests.—Gives white precipitates with lime and baryta water, and acetate of lead; soluble in excess. With potassa, when the acid is in excess, a sparingly soluble white acid tartrate (Bitartrate). Used in preparing effervescing mixtures, as the soda and Seidlitz powders; also, as a cheap substitute for lemon-juice or citric acid.

(*b*) **Racemic Acid,** $2HO,C_8H_4O_{10}$. — Is found in the juice of sour grapes. It is isomeric with tartaric acid, which it closely resembles in all its physical and chemical properties. It may be distinguished by its affording a precipitate with CaCl.

422. (*c*) **Citric Acid,** *Acidum Citricum,* $3HO,C_{12}H_5O_{11}$. The acid of lemons, limes, etc.

Prep.—By saturating lemon-juice with chalk, and decomposing the citrate of lime thus formed by sulphuric acid.

Prop.—Transparent, right rhomboidal crystals (4th system), permanent in the air; soluble in $\frac{3}{4}$ its weight of cold and $\frac{1}{2}$ of boiling water. The crystals contain four eq. water, three of which are basic; it is, therefore, tribasic. It forms citrates, of which those of potassa, magnesia, and iron are officinal. It should give no precipitate with a potassa salt.

Tests.—The citrates of lime, baryta, strontia, lead, and silver are insoluble and white.

Med. Effects.—Used in making acidulous drinks and effervescing draughts.

(*d*) **Malic Acid.**—The acids of apples, pears, garden rhubarb, etc.

Prop.—It is bibasic, and forms malates. Is not used in medicine.

(*e*) **Tannic Acid,** *Acidum Tannicum.*

423. (*f*) **Gallic Acid,** *Acidum Gallicum.*

These acids constitute the astringent principle of vegetables. Their acid character is not very marked.

Prep.— Tannic acid is best prepared on the small scale, by pouring ordinary ether upon powdered galls in a displacement apparatus. The water of the ether dissolves the tannic acid, while the ether retains the impurities. The two separate into layers; they are separated, and the tannic acid obtained by careful evaporation of the lower.

Prop.—Tannic acid is a slightly yellowish, friable, porous mass, without the slightest tendency to crystallisation. It has a pure, astringent taste; is freely soluble in water, alcohol, ether, and glycerine; reddens litmus. It precipitates albumen, gelatin, starch, gluten; the salts of lead, copper, silver, mercury, teroxide of antimony, protoxide of tin, sesquioxide of iron; sulphuric, nitric, hydrochloric, phosphoric, and arsenic acids insoluble in excess of acid; the alkaloids, the precipitate being soluble in the vegetable acids,—hence it is not to be fully relied on as an antidote.

A number of varieties of tannic acid are enumerated, that from galls being distinguished as *gallo*-tannic acid. The most important of these are: Catechu-tannic, from catechu; this does not precipitate tartar emetic, but throws down a grayish-green precipitate with the ferrous, and a brownish-green one with the ferric salts. Cocco-tannic, from *kino*, does not precipitate tartar emetic. Querco-tannic, from oak-bark, does not yield gallic acid.

424. **Gallic Acid.**—*Prep.* By the spontaneous fermentation of tannic acid when kept moist in a warm place for about a month. Oxygen is absorbed and an equal volume CO_2 evolved.

Prop.—In white, silky crystals, which melt and burn when heated, soluble in 100 parts of cold and 3 of boiling water. It does not precipitate gelatine or albumen. It gives a blue-black precipitate with the ferric salts, which disappears on heating the liquid.

Pyrogallic Acid, $C_{12}H_6O_6$, is prepared by heating gallic acid to about 420°; it sublimes in the form of brilliant white plates. $C_{14}H_6O_{10}=C_{12}H_6O_6+2CO_2$.

Prop.—It is soluble in water, has energetic reducing powers, and hence is used as developer in photography. The pyrogallate of potassa absorbs a considerable portion of oxygen, and has been used in the analysis of air. Upon the application of heat, water is evolved, and *metagallic acid* remains; $C_{12}H_6O_6 = C_{12}H_4O_4 + {}_2HO$. It is a black, shining mass, resembling charcoal, insoluble in water, soluble in alkaline solutions, from which it is again precipitated black by acids.

V. ARTIFICIAL ORGANIC BASES.

425. These are exceedingly numerous; they are mostly *substitution* compounds (383). The following examples will illustrate the almost infinite number which may exist.

(1) In dry *ammonia*, NH_3, one, two, or three equivalents of H may be replaced by the same or by different radicals. Thus, NH_2,C_4H_5 *ethyl*-amine, $NH(C_4H_5)_2$ *diethyl*-amine, and $N(C_4H_5)_3$ *trithyl*-amine; NC_2H_3, C_4H_5, $C_{10}H_{10}$, *methyl*-, *ethyl*-, *amyl*-amine. These bodies have all more or less physical analogy to NH_3, and are all well-marked bases. Where one of H is replaced, an *amidogen* base is formed; where two of H, an *imidogen*, and where all the H, a *nitrile*.

(2) *Ammonium*, NH_4, is known only in combination (275). In its compounds we may in like manner replace the H. Thus NH_4Cl may become chloride of ethylammonium, $NH_3C_4H_5Cl$, or diethylammonium, $NH_2(C_4H_5)_2Cl$, etc.; or we may replace the H by distinct radicals, as NC_2H_3, $C_4H_5C_{12}H_5$, $C_{10}H_{11}Cl$, chloride of methyl-, ethyl-, phenyl-, amyl-ammonium. Like ammonium, these substitution products are not isolable, but as hydrated oxides they form bases analogous to NH_4O,HO.

(3) The H of the introduced radical may be further re-

placed by the halogens, NO_4, and certain metals and radicals. Thus in the aniline series:

Aniline, Phenyl-amine,	$NH_2,C_{12}H_5$.
Chloraniline,	$NH_2C_{12}H_4Cl$.
Bromaniline,	$NH_2C_{12}H_4Br$.
Bibromaniline,	$NH_2C_{12}H_3Br_2$.
Tribromaniline,	$NH_2C_{12}H_2Br_3$.
Nitraniline,	$NH_2C_{12}H_4(NO_4)$.
Zincaniline,	$NH_2C_{12}H_4Zn$.
Ethylaniline,	$NH_2C_{12}H_4(C_4H_5)$.

(4) The nitrogen of the ammonia, or ammonium, may be replaced by P, As, or Sb. Thus:

$P(C_4H_5)_3$, Triethylphosphine.
$Sb(C_4H_5)_4I$, Iodide of tetrethylestibammonium.
$As(C_4H_5)_3$, Triethylarsine.

These compounds are sometimes found in organic bodies, or as products of their decomposition.

426. **Propylamine,** $C_6H_9N=NH_2C_6H_7$, is metameric (384) with Ethylmethylamine, NH,C_2H_3,C_4H_5, and Trimethylamine, $N(C_2H_3)_3$.

It may be obtained from the following bodies by distillation with lime or potassa—narcotina, codeia, and ergot; it exists also in bone oil, the leaves of Chenopodium vulvaria, several species of Cratægus (white thorn), herring or cod-fish pickle, alcohol in which anatomical preparations have been kept, human urine, etc. It is probable that in some cases the bodies extracted are not identical; that from herring pickle is trimethylamine.

Prop.—It is a clear liquid, of a pungent, ammoniacal odour, and giving white fumes when a rod dipped in HCl is held near it. That from narcotine and herring pickle has a fish-smell like many of the methyl compounds. The muriate has been used in rheumatism, in dose of gr iij to v.

Aniline, Phenylamine, $NH_2C_{12}H_5$.

Prep.—By the action of nascent H upon Nitrobenzole (418); $C_{12}H_5NO_4+H_6=NH_2C_{12}H_5+6HO$.

Prop.—A colourless oil, of an aromatic odour and vinous taste; s. g. 1·2; boils at 360°. Its salts and derivatives are used as *colouring matters*. It is poisonous like Nitrobenzole, but the symptoms are not delayed as in the former. Its sulphate is less poisonous; it has been administered in chorea in doses of gr j to vii. It produces a transient blueness of the skin and lips. Aniline is detected by the blue colour it affords with hypochlorite of lime.

VI. THE ALKALOIDS AND ALLIED PRINCIPLES.

SYLLABUS.

Morphia,	$C_{34}H_{19}NO_6+2HO$.
Narcotina,	$C_{44}H_{23}NO_{14}+2HO$. ?
Codeia,	$C_{36}H_{21}NO_6+2HO$.
Thebaina,	$C_{38}H_{11}NO_6$.
Narceina,	$C_{46}H_{29}NO_{18}$.
Opiana,	$C_{66}H_{36}N_2O_{21}$
Papaperina,	$C_{40}H_{21}NO_8$.
Phormia,	$C_{27}H_9NO_7$.
Metamorphia,	?
Quinia,	$C_{40}H_{24}N_2O_4+6HO$.
Quinidia,	$C_{40}H_{24}N_2O_4+2HO$.
Cinchonia,	$C_{40}H_{24}N_2O_2$.
Cinchonidia,	$C_{40}H_{24}N_2O_2$.
Strychnia,	$C_{42}H_{22}N_2O_4$.
Brucia,	$C_{46}H_{26}N_2O_8+8HO$.

Igasuria,	$C_{44}H_{26}N_2O_8$.
Veratria,	$C_{64}H_{52}N_2O_{16}$.
Aconitia,	$C_{60}H_{47}NO_{14}$.
Atropia,	$C_{34}H_{23}NO_6$.
Emetia,	$C_{20}H_{15}NO_5$.
Berberina,	$C_{40}H_{17}NO_8$.
Bebeerina,	$C_{38}H_{21}NO_6$.
Delphia,	$C_{27}H_{46}NO_2$.
Piperina,	$C_{34}H_{19}NO_6$.
Caffeina,	$C_{16}H_{10}N_4O_4+2HO$.
Theobromina,	$C_{14}H_8N_4O_4$.
Conia,	$C_{16}H_{15}N$.
Conhydrina,	$C_{16}H_{17}NO_2$.
Nicotina,	$C_{10}H_7N$.
Picrotoxine,	$C_{20}H_{12}O_8$.
Santonine,	$C_{30}H_{18}O_6$.
Phloridzin,	$C_{42}H_{24}O_{20}+4HO$.

THE ALKALOIDS.

427. The term alkaloid has been applied to the bases existing in vegetables and upon which their activity depends; closely allied to them are certain neuter and acid bodies derived from similar sources. The alkaloids always exist in combination with an acid, which is generally common to all the bases of the same plant. Only the most important will be considered.

Prep.—This is almost always conducted on the large scale. The following may be given as a sketch of the process, which however varies greatly. A solution of the principles of the plant is made in water; acid being added, if necessary. To this is added a base which unites with the vegetable acid, and the alkaloids, being insoluble in water, precipitate. They are dissolved by hot alcohol, and purified by animal charcoal.

Prop.—They are generally solid and crystalline, insoluble or nearly so in water, more soluble in alcohol, ether, and chloroform, and freely so in dilute acids with which they combine. They have all a more or less distinct alkaline reaction. Their taste as well as that of their salts is bitter, and they are mostly poisonous. Tannic acid, which precipitates all of them from solution, and animal charcoal, are most to be relied on as antidotes, the stomach being always promptly and thoroughly evacuated, and the general symptoms combated by appropriate measures. *Bouchardet's Antidote* consists of gr iij *Iodinii*, gr vj *Potass. iodid.* in Oj *Aquæ*, given in wineglassful doses; it is contraindicated in poisoning by *digitaline.*

Tests.—The separation of the alkaloids in cases of poisoning is difficult, and it is impossible to enter into details in a work of this compass. The general methods followed are:

(1) *Dialysis.*—The contents of the stomach, acidulated with acetic acid, are placed in a basin over which a bladder is tied; it is then inverted in a vessel of distilled water. In the course of 48 hours the alkaloid will be found in the latter, which is then to be cautiously evaporated to dryness (Letheby).

(2) *By Animal Charcoal.*—The suspected liquid, neutral or nearly so, is digested for several hours, with occasional shaking with two or three ounces of *pure* animal charcoal, which absorbs the alkaloid. After draining and washing with cold water, the charcoal is boiled with about half a pint of stronger alcohol for half an hour, in a long-necked vessel to prevent much loss by evaporation. The alcohol is distilled off, the residual aqueous solution of the alkaloids heated with a few drops of *liq. potassæ*, and agitated with ether. This will remove all alkaloids soluble in that menstruum (Graham and Hofmann).

(3) *Merck's process* consists in the use of strong acetic acid, and afterwards of alcohol alone and acidulated with acetic acid, evaporating nearly to dryness, neutralising with carbonate of potassa to precipitate the alkaloids; these are washed with cold distilled water, and again dissolved in concentrated acetic acid.

(4) *Stas's process* consists in extracting the alkaloids by digesting with strong alcohol acidulated with tartaric acid, precipitating by bicarbonate of soda, and redissolving in ether.

Even when the alkaloids are obtained in a tolerably pure state, the tests require great caution to avoid fallacy. For the quantitative determination of alkaloids in pharmaceutical preparations the iodohydrargyrate of potassium (367) may be used. Aconitia and Berberina require an amount of the solution equal to one equivalent of mercury; Atropia, Strychnia, Brucia, Narcotina, and Veratria, equal to 2 eqs.; Morphia and Conia, 3 eqs.; Nicotina 4, and Cinchona alkaloids 6 eqs.

428. **Alkaloids of Opium.**—These are Morphia, Narcotina, Codeia, Thebaina, Narceina, Papaverina, Phormia, Opiana, and Metamorphia. They exist in combination with Meconic acid, $3HO,C_{14}HO_{11}+6HO$.

General Tests for Opium.—The presence of meconic acid is conclusive. It is extracted by means of alcohol acidulated with HCl, the solution evaporated to dryness, redissolved, neutralised with magnesia, and again acidulated with HCl. The solution strikes like the sulphocyanides a blood-red colour with ferric salts. That of Meconic acid is *not* affected by a solution of terchloride of gold.

Morphia.—*Prop.* Small, brilliant, transparent, colourless, rectangular crystals (3d system), soluble in 1000 parts cold, 400 boiling water, 14 parts boiling and 20 of cold alcohol, 200 of chloroform; freely in fixed alkalies, sparingly in ammonia; is insoluble in ether. By the action of acids forms a series of soluble, colourless, bitter salts. It is fusible without decomposition, and entirely volatilised by heat. It strikes a blood-red colour with nitric acid; (so do Brucia, Delphia, and *commercial* Strychnia.) It decomposes iodic acid, liberating iodine. In powder or concentrated solution, it gives a characteristic blue colour with Fe_2Cl_3. The salts of morphia, which are made by direct combination, are colourless, soluble in water and alcohol, and insoluble in ether. *Morphiæ sulphas* is in feathery crystals, sometimes mistaken for *Quiniæ sulphas*; it is freely soluble; the crystals contain 5 eq. of water of crystallisation. The *Liquor Morphiæ Sulphatis* contains gr j to f℥j *Aquæ*. *Morphiæ Murias* is rather more soluble; *Morphiæ acetas* is generally in powder, requiring a little free dilute acetic acid to render it freely soluble. The Valerianate is much used. *Dose* of Morphia and its salts, gr $\frac{1}{8}$ to $\frac{1}{2}$.

Narcotina, $C_{44}H_{23}NO_{14} + 2HO$? — Is separated from opium or morphia by ether, in 100 parts of which cold or 50 boiling it is soluble. It is insipid, feebly basic, gives an *orange* tint with nitric acid, and a greasy stain to paper when melted on it; sulphuric acid, with a trace of nitric, gives a blood-red colour. It is not narcotic, and has been employed as an antiperiodic in as large a dose as ʒij. Proper dose, gr v to x. Is but little used.

Codeia, $C_{36}H_{21}NO_6+2HO$. — Is freely soluble in alcohol, ether, and in 80 parts cold and 17 of boiling water. It does not react with ferric salts; is coloured yellow by nitric acid. It produces tranquil sleep and much itching of the skin. Is less active than morphia; is given in doses of $\frac{1}{4}$ to $\frac{1}{2}$ gr. It is generally present in commercial salts of morphia.

Narceia, $C_{46}H_{29}NO_{18}$. —Is insoluble in ether, soluble in

230 parts of boiling water, and readily in alkaline solutions; it combines with difficulty with mineral acids; its salts are coloured blue by a little water, become colourless on dilution, and blue again on abstracting a portion of the water by fused chloride of calcium. It is the most narcotic of the alkaloids, the sleep produced by it being tranquil and not easily broken (Bernard). It appears to have a special action on the lumbar portion of the spinal cord (Ozanman).

Thebaina, or *Paramorphia*, $C_{38}H_{11}NO_6$.—Resembles in appearance narcotina; soluble in ether and alcohol, but nearly insoluble in water. It is crystallisable with difficulty; the same is true of its salts. The solution of its muriate leaves a resinous mass on evaporation. It is the most poisonous of the opium alkaloids, but is not narcotic; causes tetanus (Magendie); is excitant to the cervical part of the spinal cord (Ozanman).

Papaverina, $C_{40}H_{21}NO_8$.—In small crystals, which give a blue colour with HO,SO_3; with HCl in excess forms insoluble crystals of a high refractive power. It is insoluble in water, and sparingly soluble in alcohol and ether. It is rather stimulant than narcotic in its effects.

Phormia, or *Pseudomorphia*, $C_{27}H_9NO_7$, occurs but seldom in opium. Its reactions with nitric acid and the ferric salts are similar to those of morphia, but it is not poisonous. It does *not* decompose iodic acid.

Opiana, $C_{66}H_{36}N_2O_{21}$.—Is soluble in alcohol and ether. Paper moistened with it becomes red on exposure to the fumes of HCl (Merck's test for opium). Metamorphia is unimportant.

429. **Alkaloids of Cinchona.**

These are Quinia, Quinidia, Cinchonia, and Cinchonidia, which exist in combination with Kinic acid, $2HO,C_{14}H_{10}O_{10}$.

Quinia, $C_{40}H_{24}N_2O_4+6HO$.

Prop.—Is generally flocculent, but may be obtained in crystals; fuses at 300° without change; is soluble in 400 parts cold and 250 of boiling water; in two parts of alcohol or chloroform, and 60 of ether; also soluble in the fixed and volatile oils. Its salts are sparingly soluble in water, unless an excess of acid be present. The tannate, tartrate, oxalate, and acetate are insoluble; tartaric acid does not cause a precipitate with acid watery solutions of the sulphate. The alkaloid and its salts are characterised by the emerald-green colour produced by the action of chlorine water followed by ammonia. Quinidia, which gives a similar result, is distinguished by sparing solubility in ether. A solution of the sulphate, mixed with a little acetic acid and alcohol, gives with tincture of iodine emerald-green plates, which are nearly colourless by transmitted light, which they *polarise* (*Herapath's salt, artificial tourmaline*). Aqueous solutions of its salts are *fluorescent*, that is, render visible the chemical rays of light. The sulphate and valerianate are the only officinal salts. A fluorescent substance resembling quinia has been found in the tissues of animals by Dr. H. Bence Jones and Dr. Dupré.* As it is uncrystallisable, they have named it *Animal Quinoidin.*

Quiniæ Sulphas.—In silky crystals, containing 6 eq. of water of crystallisation and two of constituent water. It loses 4 eq. of the former at 212°, and two more at 240°. It melts at the latter temperature into a waxy mass. Is soluble in 740 parts of cold or 30 of boiling water; the latter deposits the excess on cooling; in 60 parts cold alcohol, very slightly in ether, freely in glycerine. Two drops to the grain of *Acid. Sulph. Aromat.*, dissolve it, and gtt xxiv to gr xx make an excellent pilular mass

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* *Chem. News*, No. 334, p. 197.

(Parrish); the officinal pills, which contain each gr j, become hard and are difficult of solution. *Incompatibles.*—The alkalies, their carbonates, the alkaline earths, vegetable astringents, salts of lead and baryta. *Adulterations.*—Water, known by the loss of weight in drying at 212°. Quinine is hydroscopic, absorbing in a moist atmosphere 53 p. c. *Chalk, magnesia, mannite, gum,* and other similar adulterations, are insoluble in alcohol. The salt should be entirely volatilised at a red heat, and should not effervesce or blacken with HO,SO_3. *Salicin* gives a blood-red tinge with HO,SO_3; *Phloridzin*, a yellow; *Cinchonia* gives a precipitate with K_2Cfy, insoluble in excess; also with CaCl.

Quiniæ Valerianas.—Is in white tables, having the odour of valerianic acid, and an unpleasant taste; is soluble in 110 parts cold or 40 of boiling water, which decomposes it; 6 of cold and 1 of hot alcohol, and in ether. It slowly decomposes. Dose, gr i to v.

Quinidia is isomeric with Quinia, and only distinguished by its slight solubility in ether, and by its affording a sparingly soluble precipitate with KI. Its medical effects and dose are the same.

Cinchonia, $C_{40}H_{24}N_2O_2$.—Differs from quinia only in containing 2 equivalents less of O. It is insoluble in ether, yields, when treated like quinia with iodine, a brick-red deposit; with ammonia and chlorine water gives a white deposit. Is used as a substitute for Quinia, but requires to be given in larger doses. *Cinchoniæ Sulphas* is officinal. Its crystals are anhydrous, distinct, and not silky like those of *Quiniæ Sulph.*

Cinchonidia, $C_{40}H_{21},N_2O_2$.—Isomeric with Cinchonia; constitutes the bulk of commercial quinidia. It gives the same reaction as quinia with the iodine test, and as cinchonine with chlorine water and ammonia. The oxalate of commercial quinidia (a mixture of quinidia and cinchonidia) is soluble and may be crystallised; that of quinia is insoluble.

By the action of heat on the acid sulphates of quinia and cinchonia, isomeric bodies, quinicia and cinchonicia are obtained. They are not important.

Quinoidine, or *Chinoidine*, appears to be a mixture of uncrystallisable Quinia and Cinchonia; it is sold as *Extract of Bark*. It is soluble in *Acid. Sulph. aromat.*, and is given for the same purposes as Quinia, in doses twice as large.

430. *Strychnia*, $C_{42}H_{22}N_2O_4$.

Sources.—Together with Brucia, and combined with Igasuric acid, $C_8H_6O_{10}$?, in Nux Vomica, St. Ignatius' bean, false Augustura, and the Upas.

Properties.—Is generally in powder, but may be obtained in right square prisms (2d system) of an intensely bitter taste said to be perceptible in 600,000 parts of water. Soluble in 6667 parts of water at 50°, and 2000 at 212°, in 387 of officinal alcohol, 179 of absolute alcohol, 682 of ether, and 5 of chloroform, its best solvent; also in the volatile oils and acid solutions. It melts, but does not volatilise. Its salts are soluble, crystalline, and, like the alkaloid, highly poisonous, one grain having proved fatal. It produces tetanic symptoms which come on soon after it has been taken. Lard and camphor have been proposed as special antidotes in addition to the general ones already mentioned. The tetanic symptoms are best combated by chloroform.

Tests.—(1) Evaporate the suspected solution to dryness, add a drop of concentrated sulphuric acid, and then a small crystal of bichromate of potassa; a blue colour is produced which changes to purple, violet, and crimson.

This, it is stated, will detect the $\frac{1}{500000}$ part of a grain.

(2) The suspected solution is applied to the back, previously dried, of a young frog fresh from the pond, or is injected into the stomach. Tetanic symptoms reveal the presence of the poison. Pure strychnia is coloured yellow by HO,NO_5, but owing to the presence of Brucia, the commercial drug is tinged orange or red.

Strychniæ Sulphas.—In colourless, efflorescent crystals, wholly volatilised by heat and soluble in water. Dose of strychnia and its salts, $\frac{1}{18}$ gr. gradually increased.

Brucia, $C_{46}H_{26}N_2O_8+8HO$.—Is more soluble than strychnia, requiring but 850 parts of cold and 500 of boiling water; is very soluble in alcohol, insoluble in ether. *Tests.*—A blood-red colour with HO,NO_5, changing to yellow with heat, and violet with SnCl (distinction from Delphia, which becomes black and carbonaceous by SnCl). Does not decompose IO_5 (distinction from morphia). In its effects it resembles strychnia, but is only about $\frac{1}{12}$ as strong.

Igasuria, $C_{44}H_{28}N_2O_8+6HO$.—Closely resembles Brucia in all its properties, but is soluble in 200 parts of cold water. Its salts are precipitated in the presence of tartaric acid by the bicarbonate of the alkalies. Sulphuric acid imparts a rose-colour which turns greenish. According to Schützenberger, there are nine distinct alkaloids in what is known as igasuria.

431. *Veratria,* $C_{64}H_{52}N_2O_{16}$.

Sources.—*Veratrium Album* and *V. Viride.*

Prop.—As obtained by the officinal process, it is in powder, and contains Sabadillia $C_{40}H_{36}N_2O_{10}$, and Jervia $C_{60}H_{46}N_2O_6$, along with true veratria. It is errhine and causes pricking when applied to the skin. Is characterised by a red colour with HO,SO_3, and a yellow with HO,NO_5. It is not volatile.

432. *Aconitia,* $C_{60}H_{47}NO_{14}$.

Sources.—*Aconitum napellus.*

Prop.—As obtained by the officinal process, is a yellowish-white powder without smell, of a bitter, acrid taste, producing a characteristic sense of numbness on the tongue. Soluble in 150 parts cold and 5 of boiling water; readily soluble in alcohol, ether, and chloroform. Is the most poisonous of the alkaloids, dangerous symptoms having been produced by $\frac{1}{50}$ of a grain of the pure base.

Tests.—The alkaloid fuses and burns with a yellowish, smoky flame; its salts evaporate to a gummy residue; heated in a tube, it fuses and gives off at first alkaline, then acid vapours. HO,NO_5 dissolves it without change of colour; HO,SO_3 gives a yellow colour, and on adding a crystal of $KO,2CrO_3$, a green (Cr_2O_3) is produced. The numbness produced upon application of even $\frac{1}{100}$ of a grain dissolved in alcohol and rubbed into the skin, or cautiously applied to the tongue, is characteristic.

433. *Atropia*, $C_{34}H_{23}NO_6$, from *Atropa belladonna.*

Prop.—In silky crystals resembling somewhat those of sulphate of quinia. *Soluble* in 300 parts cold and 50 of boiling water, 1½ parts cold alcohol and 25 parts of cold ether; freely in dilute acids. Fuses at 194°, and volatilises at 212°. Is only suitable for external use; the *Extract. Belladonnæ* being safer for internal administration. Used to dilate the pupil and in neuralgia.

Tests.—These are not very reliable. It turns yellow with HO,NO_5, is dissolved by HO,SO_3, forming a colourless solution which becomes red on heating; its salts are coloured red by tincture of iodine.

Atropiæ Sulphas, is soluble in water, insoluble in ether. Is used as a local anæsthetic. *Daturia*, from stramonium, is said to be identical with Atropia.

434. *Emetia*, $C_{20}H_{15}NO_5$, from *Cephaelis ipecacuanha.*

Prop.—In white, uncrystallisable powder, fusing at

122°; very soluble in alcohol, and freely in boiling water. Its reactions resemble those of morphia, except with the ferric salts and iodic acid. It is but little used.

435. *Berberina*, $C_{40}H_{17}NO_8$.

Sources.—In species of *Cocculus* (*Calumba*) *Coptis*, *Hydrastis*, *Berberis*, *Podophyllum*, and *Xanthoxylum*.

Prop.—In yellow needles, insoluble in ether, readily soluble in boiling water and alcohol. HO,SO_3 dissolves it, giving an olive-green (HO,NO_5) red with fumes of NO_4. Its muriate is sold as *hydrastin*, which should not be confounded with hydrastia, a base obtained from *Hydrastis Canadensis*. The alkaloid and its salts are tonic; dose, gr iij. It is also used as a dye.

436. *Bebeerina*, Nectandria, $C_{38}H_{21}$, NO_6?, from Nectandra.

Prop.—A pale-yellow, amorphous, resinous body, slightly soluble in water, freely in alcohol and ether. Is fusible at 356° and inflammable. Its salts are uncrystallisable. The sulphate has been used as a tonic and antiperiodic; dose, gr ij or more.

437. *Delphia*, $C_{27}H_{46}NO_2$; from Delphinium.

Prop.—A white powder, slightly soluble in cold water, freely so in alcohol and ether. Reacts like morphia with HO,NO_5, but is blackened by the after-action of SnCl, and does not decompose IO_5.

438. *Piperina*, $C_{34}H_{19}NO_6$, from pepper.

Prop.—Colourless crystals, slightly soluble in water, more so in ether, and still more in alcohol. Melts at 212°, losing 2 eq. water. HO,SO_3 dissolves it, producing a deep red colour. It is decomposed by HO,NO_5; has a hot and not bitter taste. By long boiling in an alcoholic solution of KO,HO, splits into Piperic Acid $C_{24}H_{10}O_8$ and Piperidina $C_{20}H_{11}N$ (ethyl-allyl-amine $NH(C_4H_5,C_6H_5)$. Piperina is frequently added to *Quiniæ Sulphat.* in dose of gr ij, or more to increase its antiperiodic effects.

439. *Caffeina*, Theina Guarina, $C_{16}H_{10}N_4O_4$.

Sources.—The berry and leaves of the coffee-tree, *Caffea;* tea, *Thea Chinensis;* guarana, *Paullinia sorbilis;* and Paraguay tea, *Ilex Paraguayensis.* Guarana contains 5·07 p. c., black tea 1·97, green tea 1, and coffee 0·8 to 1; Paraguay tea, 1·2 of the base.

Prop.—In transparent, hexagonal plates or needles (6th system); is soluble in alcohol, ether, chloroform, and hot water. Melts at 352°, and volatilises unchanged at 725°; is not bitter. It forms well-defined salts. Is said to be poisonous, but the citrate has been given in grain doses in sick-headache. *Theobromina*, $C_{14}H_8N_4O_6$, from the cocoa-nut, resembles caffeina, but has a bitter taste, and is much less soluble.

440. *Conia* and *Nicotina* are oily liquids, of an alkaline reaction, not pre-existing in the plants, and containing no oxygen.

Conia, $C_{16}H_{15}N$, from *Conium maculatum*, by distillation with KO,HO. Is colourless, s. g. ·87, of a characteristic odour, soluble in 100 parts cold water, freely in alcohol, ether, and the fixed and volatile oils. It is very poisonous. It may be regarded as bibutyrylamine, $NH(C_8H_7)_2$; by oxidation it yields butyric acid. The plant contains a distinct alkaloid, *Conhydrina*, $C_{16}H_{17}NO_2$.

Nicotina, $C_{10}H_7N$, from *Nicotiana tabacum*, by distilling with KO,HO. Is colourless, s. g. 1·048; has the odour of tobacco, and is more sparingly soluble than Conia; very poisonous. Havanna tobacco contains 2, Maryland 2·3, Virginia 6·87, and Kentucky 6·09 per cent.

441. *Substitution Products of the Alkaloids.*—By acting on the alkaloids with iodides of methyl, ethyl, etc., a portion of the hydrogen of the alkaloid may be replaced by the radical. This fact is interesting in a theoretical point of view, as indicating the probable constitution of these bodies, placing

them among the substitution ammonias and compounds of ammonium (425). The natural alkaloids are found to be nitrile bases (425). *Methyl strychnia*, $C_{42}\frac{H_{21}}{C_2H_3}N_2O_4$, is said not to be poisonous.

442. *Neuter or Acid Bitter Organic Principles.*—These are even more numerous than the alkaloids; they contain no nitrogen; many of them are glucosides (395); of others only the empirical formula is known. The following are sometimes employed in medicine: Salicin, Phloridzin ($C_{42}H_{24}O_{20}+4HO$); Colocynthin, Santonin ($C_{30}H_{18}O_6$); Colchicin, Digitalin ($C_{54}H_{45}O_{30}$?), an active poison and alōin. Picrotoxin, $C_{20}H_{12}O_8$, is the active principle of the *Cocculus indicus.* Phloridzin, santonin, and picrotoxin are regarded as acids. It may be said that every vegetable substance employed in the *materia medica* contains one or more alkaloids, acid or neuter bitter organic principle, and often both. The plants yielding fixed and volatile oils are sometimes exceptions to this rule.

VII. FATS AND OILS.

I. FIXED; II. VOLATILE.

I. Fixed Oils.

443. *Sources.*—The animal and vegetable kingdoms. From the former, by gently heating the natural fatty matters (*rendering*) when the true fat runs out of the cellular tissue and is collected. From the latter by expression, sometimes aided by heat; by boiling and by the solvent action of benzine.

Prop.—Are greasy to the touch, lighter than water, and leave a spot on paper which does not disappear when heated. When pure, are mostly colourless and free from smell and taste; in some cases they are accompanied by volatile acids which give characteristic odour and flavour; these may often be removed by the action of animal charcoal and magnesia. They are insoluble in water, nearly so in alcohol, except castor oil which will dissolve in its own weight of stronger alcohol; ether, the volatile oils, benzine, and bisulphide of carbon dissolve them freely. Heated alone, above 500°, they are decomposed, an acrid body, acrolein $C_6H_4O_2$, and other odorous substances being evolved; if decomposed by steam at this temperature, they merely separate into their proximate constituents, glycerine $C_6H_8O_6$, and volatile fatty acids. At a higher temperature, marsh gas C_2H_4, olefiant gas C_4H_4, and complex organic products are produced. Exposed to the air, they either dry into a varnish, as linseed and poppy oils, or become rancid. The drying quality of oil is increased by the addition of 10 per cent. of PbO or MnO_2.

Saponification.—By the action of alkalies, alkaline earths, and certain metallic oxides, soaps are formed, glycerine being at the same time set free. The soaps of KO and NH_4O are soft, of NaO hard, of CaO and PbO insoluble. The latter constitutes *Emplastrum plumbi.* The soaps formed with vegetable oils, as castile, *Sapo* (olive oil), and palm (*palm oil*), are soluble in cold alcohol.

444. **Fatty Acids.**—These may be obtained by decomposing soap by a mineral acid, or directly as above stated. They are generally homologous (384) with acetic acid; some of the lower members of the series are found free in the animal secretions, etc. (415). They are liquid, volatile, and of decided and generally offensive odour. The higher members of the series are solid, white, fusible,

volatile, tasteless, and inodorous. *Oleic* acid belongs to another series. The combinations of the fatty acids with oxide of allyl, $C_6H_5O_3$, are distinguished by the termination *in*, as *stearin*, *margarin*, and *olein*. These three bodies constitute the bulk of solid fats. Olein remains liquid when the fat is exposed to cold, and may be separated by decantation or pressure.

Stearic Acid, $HO,C_{36}H_{35}O_3$.—Is white, inodorous, tasteless, of a slight acid reaction, fusing at 160°; may be distilled in vacuo, but not in air. Is insoluble in water, cold alcohol, and ether.

Margaric Acid, $HO,C_{34}H_{33}O_3$.—Closely resembles the former, melts at 140°. It is probably a mixture of stearic with palmitic acid, $HO,C_{32}H_{31}O_3$, obtained from palm oil.

Oleic Acid, $HO,C_{36}H_{33}O_3$, is a colourless liquid, insoluble in water, soluble in alcohol and ether, of an acid reaction and sharp taste; it is solid at 50°. It is readily oxidised. The following acids are among the remaining most important fatty acids.

Butyric $HO,C_8H_7O_3$, *Caproic* $HO,C_{12}H_{11}O_3$, *Caprylic* $HO,C_{16}H_{15}O_3$, *Capric* $HO,C_{20}H_{19}O_3$, exist in butter and the animal secretions. They are colourless and offensive; the first has been described (413). Caproic acid has a smell resembling acetic acid; Caprylic acid, that of the sweat of the negro, and Capric, that of the goat. They are all liquid, colourless, and their boiling-points vary with the proportion of C and H present (384).

Laurinic Acid, $HO,C_{24}H_{23}O_3$, exists in the cocoa-nut oil and in spermaceti; *Myristic* $HO,C_{28}H_{27}O_3$, in the expressed oil of nutmegs; *Palmitic* $HO,C_{32}H_{31}O_3$, in palm oil, butter, lard, olive oil, and probably in all fats in which margaric acid has been supposed to exist.

It will be noticed that the homologous series of fatty acid runs from butyric acid C_8 to stearic C_{36},—omitting every other term. We have no animal fatty acid of this series, the C of which is not evenly divisible by 4. Cerotic acid, $HO,C_{54}H_{53}O_3$, is the highest member of the series found in nature. Homologous with oleic acid we have, *Acrylic* acid, $HO,C_6H_3O_3$, all the salts of which are soluble; *Crotonic*, $HO,C_8H_5O_3$, from croton oil; *Dumaluric*, $HO,C_{14}H_{11}O_3$, from urine; *Moringic*, $HO,C_{30}H_{27}O_3$, from oil of ben; *Hypogæic*, $HO,C_{32}H_{29}O_3$, from whale and porpoise oil; and others of even less importance. *Ricinoleic* acid, $HO,C_{38}H_{35}O_3$, is obtained from castor oil. The fatty acids have been formed artificially from inorganic matters.

445. **Glycerine,** *Glycerina,* $C_6H_8O_6 = C_6H_5O_3,3HO$.—Is obtained from fats by the action of steam at about 500°, by saponification, or by *inverse* saponification by HO,SO_3. That obtained by the first-named process is the purest.

Prop.—A colourless, inodorous, syrupy liquid, of a sweetish taste and fermentable (Berthelot); s. g. 1·273; officinal s. g. 1·25; is soluble in all proportions in water and alcohol, insoluble in ether; does not dry or become rancid on exposure to the air; it cannot be distilled alone, but gives off *acrolein*, C_6H_3O,HO, and which by oxidation yields acrylic acid, $HO,C_6H_3O_3$. It combines with acids. *Nitroglycerine*, or *glonoine*, $C_6\frac{H_5}{(NO_4)_3}O_6$, is formed by the action of a cooled mixture of sulphuric and nitric acids (386) on glycerine. It is an explosive, colourless, oily liquid; s. g. 1·6; freezing at 46°; soluble in 180 parts of water, and freely in alcohol and ether. A single drop applied to the tongue produces intense headache, with vascular excitement. Death from a larger quantity has been recorded. There is no known antidote. With sulphuric and phosphoric acids, glycerine forms *sulpho-* and *phospho-glyceric* acids. The latter exists in the brain and in the yolk of eggs. The *solvent powers* of glycerine are intermediate between those of alcohol and water. It will dissolve 2 of one p.c. of phosphorus, one of iodine, 33 of KI, ten of HgCl, 2 of *Quiniæ sulphas*, 6 of *Acid. tannic*, 4 of strychnia salts, 2 of *Atropia*. Bromine, ammonia, and nitrate of silver, are soluble in all proportions in pure glycerine. Generally speaking, all deliquescent salts are soluble in it, also the vegetable acids. Alum, and the sulphates of iron, copper, and zinc, are soluble to the extent of from 25 to 40 p. c. It is miscible with Goulard's Extract and lead water. It is used as a vehicle for the administration of medicines, and as an emollient. It should afford no precipitate with AgO,NO_5 (absence of chlorides), or with NH_4S,HS or K_2Cfy (absence of the heavy metals).

Glycerine does not pre-exist in fats, but is formed at the time of saponification. The so-called oxide of glyceryle, or of lipyl, $C_6H_5O_3$, is the oxide of allyl, the base proper of fats. When glycerine and fatty acids are heated together in sealed tubes, they unite, re-forming the fats. Hence a fat is considered to be a compound of a fatty acid with oxide of allyl. Glycerine is regarded as a *triatomic alcohol*, in which one, two, or three eq. of the water may be replaced by an acid. Thus in Stearine, a component of the solid portion of fats, we may have:

Monostearin, $C_{42}H_{42}O_8 = C_6H_5O_3,2HO,C_{36}H_{35}O_3$ (Stearic acid).
Bistearin, $C_{78}H_{76}O_{10} = C_6H_5O_3,HO,2(C_{36}H_{35}O_3)$.
Tristearin, $C_{114}H_{110}O_{12} = C_6H_5O_3,3(C_{36}H_{35}O_3)$.

Not only does glycerine unite with the organic, but also with some of the inorganic acids. The number of compounds which may be formed is very great (379).

Synthesis of Glycerine.—This subject is interesting on account of the possible production of a natural fat from purely inorganic materials.

Terbromide of allyl, $C_6H_5Br_3$, may be obtained by the action of iodide of phosphorus, and afterwards of Br, upon glycerine.

This reacting with acetate of silver, $AgO,C_4H_3O_3$, yields *triacetine* ; $C_6H_5Br_3 + 3(AgO,C_4H_3O_3) = C_6H_5O_3,3(C_4H_3O_3) + 3AgBr\downarrow$. Triacetine, boiled with KO.HO, yields glycerine; $C_6H_4O_3,3(C_4H_3O_3) + 3(KO,HO) = C_6H_5O_3,3HO_{\rightarrow} + 3(KO,C_4H_3O_3)_{\rightarrow}$. As most of the fatty acids may be synthetically obtained, and as they may be directly combined with glycerine, it only remains to determine whether $C_6H_5Br_3$ may be formed from inorganic materials. An isomeric compound, $C_6H_5BrBr_2$, *Bromide of bromopropylene*, may be prepared by the action of bromine upon the products of the decomposition of amylic alcohol, $C_{10}H_{11}O,HO$, at a red heat. With the silver salt, however, this yields chiefly a compound, $C_6H_4O_2,2C_4H_3O_3$, but at the same time a *small quantity* of triacetin, $C_6H_5O_3,3C_4H_3O_3$, is produced by a secondary reaction.* As amylic alcohol may be formed from purely inorganic substances,† it would seem that the synthesis of a fat is possible.

II. Volatile Oils.

446. *Sources.*—From plants by distillation with water; by expression, or by maceration in fat (*enfleurage*).

Prop.—They are fragrant, of a hot taste, lighter than water (except those of sassafras, gaultheria, pimento, and cloves), inflammable, and do not leave a permanent stain on paper. They dissolve in small quantity in water, to which they communicate their odours (*Aquæ medicatæ*), freely in alcohol and ether. Nitric acid, iodine, and bromine act upon them violently, sulphuric acid more quietly; they do not saponify. They are conveniently divided into those containing (*a*) carbon and hydrogen; (*b*) carbon, hydrogen, and oxygen; (*c*) containing also sulphur.

(*a*) *Containing C and H.*

447. These are all isomeric with oil of turpentine, $C_{20}H_{16}$, but vary in s. g. and boiling-point; when absolutely pure, are inodorous, but as met with have various odours, which appear to be developed by oxidation. But little is known of their true chemical character.

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* WURTZ, cited in GMELIN'S *Handbook, Cavendish Ed.*, vol. xiii. p. 553.

† BERTHELOT, *Chémie organique fondée sur la Synthèse*, t. i. pp. 83, 119.

Oil of Turpentine, $C_{20}H_{16}$.—Is too well known to need description. By the action of HCl is converted into artificial camphor, $C_{20}H_{16}HCl$; similar compounds are formed with other hydrogen acids. The following are other members of this class: oils of camphor, elemi, myrrh, copaiba, black pepper, hemlock, juniper, savin, lemon, orange, and cedar.

(*b*) *Containing C, H, and O.*

448. They form the great bulk of the volatile oils. On exposure to cold, they generally separate into an oily portion isomeric with oil of turpentine (elæopten), and a crystalline, solid, camphor-like body (stearopten) containing oxygen. With nitroprusside of copper, $Cu_2Fe_2Cy_5NO_2$, they give marked, and in some cases characteristic colours. The action of this reagent is interfered with by the presence of the hydrocarbon volatile oils. In some cases, as the oils of cinnamon, gaultheria, spirea, and bitter almonds, their rational formula has been determined, and they have been formed artificially. The following are officinal: Oil of anise, bergamot, chenopodium, cajuput, cloves, cinnamon, Canada fleabane, fennel, gaultheria, pennyroyal, juniper, lavender, the mints, allspice, roses, rosemary, sassafras, thyme, and valerian.

(*c*) *Containing Sulphur.*

449. They are highly pungent, and of powerful odour. They may be considered as sulphur compounds of the radical *allyl* C_6H_5. According to some, a distinct radical, *ferulyle*, $C_{12}H_{11}$, exists in assafœtida. Oil of garlic is sulphide of allyl, C_6H_5S; Oil of mustard, a sulphocyanide, $C_6H_5C_2NS_2$. It has been formed artificially by the reaction of KCsy with C_6H_5I. Oil of horseradish is identical with oil of mustard.

CAMPHORS AND RESINS.

These are the products of the oxidation of volatile oils; they are too numerous for special consideration.

450. **Camphor,** *Camphora,* $C_{20}H_{16}O_2$, may be taken as the type of the group. It is solid, colourless, volatile, inflammable; soluble in 1000 parts water (*Aqua Camphoræ*), and freely in alcohol (*Spiritus Camphoræ*), also in chloroform and strong acetic acid. A clean fragment of camphor thrown upon water rotates in a remarkable manner; the least trace of grease instantly arrests the movement.

Resins.—Those containing benzoic acid, $C_{14}H_6O_4$, are called *balsams*, as tolu; when they contain gum, *gum resins*, as assafœtida. The latter form a milky emulsion with water; alcohol dissolves only the resinous portion. Oleo-resins contain volatile oils, as crude turpentine and copaiba.

VII. COLOURING MATTERS.

451. **Indigo.**

Sources. — Various species of Indigofera and genera of other families; an allied substance is sometimes found in the urine. It appears to exist in the plant in the form of a soluble, colourless compound; it is extracted by fermentation as a yellow liquid which yields a precipitate of blue indigo upon the addition of lime.

Prop. — Commercial indigo is in deep blue, insoluble masses, which on heating yield a blue vapour which condenses into crystals. It contains 50 p. c. of indigo-blue, *indigotine*, $C_{16}H_5NO_2$, which by reducing agents, as HO,

So_3, takes up an atom of H and becomes indigo-white, *Indigogene* $C_{16}H_6NO_2$, which again becomes blue on exposure to the air. Nordhausen sulphuric acid, $HO,2SO_3$, dissolves indigo, forming sulphindigotic or sulphindylic acid, $C_{16}H_4NO_2,S_2O_2$, and sulphopurpuric acid, $C_{32}H_{10}N_2O_4$, $2SO_3,HO$. These are used in dyeing. By oxidising agents and KO,HO, it yields various products, among others aniline and picric acid, $HO,C_{12}H_2(NO_4)_3O$.

452. **Aniline**, $NH_2C_{12}H_5$, is obtained indirectly from coal-tar (417). By the action of $KO,2CrO_3$, AsO_3, $SnCl$, $HgCl$, etc., it yields colours of various shades, chiefly crimson and purple, and known as magenta, mauve, solferino, etc. By combination, all tints have been obtained. The composition of these colours is complex, and in many cases unknown. They have been successfully used in injecting tissues for microscopic examination.

453. **Picric Acid,** Carbazotic acid, Trinitrophenic acid, $HO,C_{12}H_2(NO_4)_3O$, may be regarded as a substitution compound in which 3 eq. of H of Phenic acid (417) are replaced by NO_4. It is obtained by the action of nitric acid upon oil of tar, also upon silk, indigo, salicin, and aniline.

Prop.—In yellow crystals, soluble in 86 parts water, of a bitter taste, and decomposed by heat with explosion. It is used as a yellow dye, as a test for potassa, and has been administered as an antiperiodic. It is said to be used to adulterate beer, but may readily be detected, not being removed by animal charcoal.

454. *Litmus*, is obtained from various lichens by oxidation and the action of ammonia. Is usually in the form of cubes of plaster of Paris, saturated with the colouring matter. It is soluble in water and alcohol, is reddened by acids, and the red colour restored by neutralising agents. Hence its use as a test. It contains three colouring prin-

ciples,—Lecanosic acid, $HO,C_{16}H_8O_8$, Orcin, $C_{14}H_8O_4,HO$, and Orceine, $C_{14}H_8NO_6,HO$. *Turmeric*, the root of *Curcuma longa*, yields a yellow tincture which is turned brown by alkalies. *Quercitron*, the inner bark of *Quercus nigra*, *Fustic*, the wood of *Morus tinctoria*, *Saffron*, portions of the flowers of *Crocus sativa*, and *Annoto*, from the seeds of *Bixa orellana*, are all used as yellow dyes.

455. *Madder.*—The root of *Rubia tinctorum*. It contains three colouring principles: *Xanthin*, C H O yellow; *Alizarine*, $C_{20}H_6O_6$, red; and *Purpurine*, $C_{18}H_6O_6$, purple. Artificial alizarine obtained from naphthaline cannot be considered identical with that from madder. The root is officinal and is used as an emmenagogue. The madder colours are remarkable for purity and permanence.

456. *Logwood.*—The wood of *Hæmatoxylon Campechianum*. It contains *Hæmatoxyline*, $C_{16}H_7O_6,3HO$. Is used for purple and black dyes. Is officinal and used as a tonic and astringent.

Brazil Wood is used for red dyes, red ink, etc.; with alum, forms a crimson lake; it contains *Braziline*, $C_{36}H_{14}O_{14}$. It is not used in medicine.

457. *Carthamine*, Safflower, the petals of *Carthamus tinctorius*, is used as a fine red dye and in the preparation of *rouge*. It contains *Carthamine*, $C_{26}H_9O_5,2HO$, a yellow substance which by oxidation yields red *Carthamic acid*, $C_{26}H_9O_7$. *Alkanet*, the root of *Anchusa tinctoria*, yields a red tincture used in thermometers, etc.; it contains *Anchusine*, $C_{17}H_{10}O_4$. *Santalum*, Red Sanders, is the wood of *Pterocarpus Santalinus*; it contains a white crystalline principle, *Santaline*, which oxidises to red *Santaleine*, $C_{16}H_8O_3$?

458. *Lac.*—Is a resinoid substance exuding after the puncture of an insect from species of *Ficus*. It yields a scarlet dye. It is especially used in the preparation of varnishes, sealing-wax, etc.; it is freely soluble in alcohol.

459. *Cochineal.*—The female of a species of *coccus.* The insect yields its colouring matter to water and alcohol. By precipitation with alumina it yields carmine. The insect is sometimes used as a reputed antispasmodic.

460. COLOURING MATTER OF LEAVES AND FLOWERS.

Chlorophylle, the green colouring matter of leaves and herbage, yields *Chlorophylline*, $C_{18}H_9NO_8$. It is freely soluble in ether; long exposed to the air, it forms *Xanthophylline*, which is also found in the yellow leaves of autumn; the red leaves contain *Erythrophylline*. The colouring matters of flowers are not well understood. Some of them, from their sensitiveness to the action of chemical agents, are used as tests. Violets give a blue juice, or infusion, which is changed to red by acids, and green, and finally yellow, by alkalies. The infusion of petals of the red rose is turned red by acids, and green by alkalies. An infusion of the common purple cabbage is similarly changed. These tests are best preserved by saturating porous papers with the juices, and drying carefully. All test-papers must be kept from air and light. The red cabbage-leaves may be preserved by careful drying.

VIII. PROXIMATE PRINCIPLES NOT OTHERWISE CLASSIFIED.

461. This includes the proximate principles of animals and vegetables, and the analysis of their secretions and excretions. The non-nitrogenised proximate principles of vegetables were considered in group I., and their nitrogenised crystallisable bases in group V. The results of

researches on this part of the subject are exceedingly discordant. This may be explained by the fact that the proximate principles cannot be obtained crystallised, and, therefore, no absolute certainty as to their composition exists. The same principle also varies according to its source; the varieties of albumen from the egg, the serum, the brain, the skin, etc., are not identical. The secretions or excretions of the body vary much in health, and greatly in disease. It is often difficult to say whether a substance pre-exists in an organised body, or is the result, in some degree, of the methods employed in its extraction, upon some other body. Some principles, as fibrin, are different when living and dead.

462. **Albumen.**—Is the most widely diffused of the proximate principles in the animal body. It exists in a liquid form in the serum of the blood (seralbumen), in white of egg (ovalbumen), in lymph, chyle, saliva, pancreatic and seminal fluids, humours of the eye, and, in disease, in the bile and urine. As a solid, it exists in the brain, nerves, glands, cellular membrane, skin, hair and nails. In vegetables, as *emulsion* or syneptase, it is also abundant, existing in the juices of some, as the potato, carrot, and asparagus; in grain and in nuts.

Prop.—In solution, is clear, slightly viscid, leaving a glairy streak on paper; when dried, is yellowish, transparent, and horny, and not then prone to decomposition. Exposed to heat, the solution coagulates at about 170°. It is then insoluble in water, but soluble by continued boiling in hydrochloric acid or in strong alkalies. When dried, this is indistinguishable from uncoagulated albumen, except by its insolubility. Heat will detect $\frac{1}{1000}$ of albumen in solution. It is coagulated by nitric and metaphosphoric acids; Tannic acid forms with it an insoluble compound analogous to that produced with gelatine. Sulphuric and hydrochloric acid precipitate it soluble in excess; acetic, tartaric, oxalic, and gallic acids do not affect it. It forms cements with the alkaline earths; that made of lime and white of egg is very adhesive and resists many chemical agents. With the salts of most of the heavy metals it forms insoluble compounds; hence it is used as an antidote. Conversely, corrosive sublimate or subacetate of lead form delicate tests for albumen, and the metallic salts are useful as antiseptics. It is also coagulated by alcohol, creasote, and phenic acid, and its acetic solution by chloride of sodium, nitrate of potassa, and sulphate of soda.

Coagulation by heat is prevented by the presence of excess of alkali or of small quantities of mineral acid. The chemical changes taking place during the process are not understood. Seralbumen is not affected by ether and oil of turpentine, which coagulate ovalbumen. The following bodies closely resemble albumen in composition and properties: *Musculin*, from fibre of flesh; *Globulin*, which constitutes the greater part of the red corpuscles of the blood: it is coagulated by strong alcohol, and redissolved by that reagent when dilute and boiling; *Pepsin*, from the gastric juice; *Pancreatin*, from pancreatic juice: it is coagulated by sulphate of magnesia; *Ptyalin*, from saliva; *Mucosin*, found in mucus; *Neurine*, the semifluid substance of the tubes and corpuscles of the brain and nerves. *Pyein* from pus, *Echidnine* from viper poison, and *Crotaline* from that of the rattlesnake, are highly poisonous when introduced into the circulation. Vegetable albumen, *Emulsin*, differs in being coagulated, like casein, by rennet and by tribasic phosphoric acid, $3HO,PO_5$.

463. **Fibrin.**—From its property of spontaneous coagulability, is unknown chemically in the soluble state. It is maintained in the soluble state in the blood by ammonia.

As obtained from blood by whipping with twigs, it is in white filaments, which gelatinise and dissolve in dilute acetic and hydrochloric acid, and in $3HO,PO_5$. It is also soluble in alkalies, which convert it into a substance closely resembling albumen. Tannic acid forms with it an insoluble imputrescible compound. The fibrin of venous and arterial blood differs, and that of flesh, *musculin*, more nearly resembles albumen.

Gluten, from wheat flour and seeds, appears to be identical with fibrin.

464. **Casein.**—Exists in milk, and perhaps in the blood. It closely resembles albumen, but is coagulated by acetic acid. Is a white, curdy substance, insoluble in water, soluble in weak alkaline solutions, from which it is again precipitated by acids. When dried, is transparent and horn-like. Is not coagulated by heat. Certain animal membranes, as rennet, coagulate it, and this action is aided by heat. *Legumin*, obtained from peas, beans, etc., is considered to be identical with casein.

466. The three bodies just described are known as the *protein* compounds. The following analyses represent their composition, but can only be considered as approximate.

	Albumen.	Fibrin.	Casein.
Carbon,	53·5	52·7	53·83
Hydrogen,	7·0	6·9	7·15
Nitrogen,	15·5	15·4	15·65
Oxygen,	22·0	23·5	23.37
Sulphur,	1·6	1·2	
Phosphorus,	0·4	0·3	

Liebig gives the following as their formulæ:

Albumen,	$C_{216}H_{169}N_{27}O_{68}S_2$
Fibrin,	$C_{298}H_{228}N_{40}O_{92}S_2$
Casein,	$C_{288}H_{228}N_{36}O_{90}S_2$

467. **Protein.**—Mulder observed, that when any one of the foregoing compounds was digested in caustic potassa until no precipitate was afforded with a lead salt, and precipitated by acetic acid, a snow-white flocculent substance was obtained, which, he stated, could be procured entirely free from sulphur and phosphorus. This substance, combined with sulphur and phosphorus, he stated, gave albumen, fibrin, and casein. The formula $C_{24}H_{17}N_3O_8$ has been assigned to it. Its existence is doubted by many, but the designation *protein compounds* is a convenient one.

468. **Gelatin.** — Exists in the skin, tendons, etc., and is derived from the *ossein* of bones by long boiling.

When pure and dry, is a transparent, colourless, inodorous, insipid solid; insoluble in alcohol and ether, soluble in boiling water, to which one per cent. will communicate the property of gelatinising; the facility with which the liquid becomes firm is greater as the temperature is lower, and varies with the variety of gelatin. The solution, exposed to the air, soon putrefies. It is soluble in all dilute acids except tannic, which precipitates it and forms an imputrescible mass (leather). It is not precipitated by alum, the acetate or subacetate of lead. Is precipitated by chloride and nitrate of mercury, but not generally by the salts of the heavy metals. Tannic acid will detect $\frac{1}{5000}$ of gelatin in solution; it is not precipitated by gallic acid. The doubtful formula $C_{13}H_{10}NO_5$ has been assigned to gelatin.

Strong nitric acid with gelatin yields oxalic acid. Sulphuric acid gives *leucin*, $C_{12}H_{13}NO_4$, *tyrosin*, $C_{18}H_{11}NO_6$, and *glycocoll*, or sugar of gelatine, $C_4H_5NO_4$; the latter is sweet, of sparing solubility, and does not ferment. Tyrosin, $C_{18}H_{11}NO_6$, is also obtained with leucin by the action of KO,HO upon casein.

Isinglass, *Ichthyocolla*, is a pure form of gelatin obtained from the swimming-bladder of fishes; it is more slowly soluble than ordinary gelatin. The finer varieties of gelatin are also known and sold indiscriminately as gelatin or isinglass. Glue is an impure gelatin; liquid glue is a solution of gelatin in strong acetic acid or in water, with the addition of nitric acid. Size is a very impure glue used to give a *surface* to paper, etc.

Chondrin, obtained by the action of boiling water upon *Cartalagin* found in the cartilages, differs from gelatin in being precipitated by acetic acid (soluble in excess), also by nitric acid and subacetate of lead. Its formula is given as $C_{32}H_{26}N_4O_{14}$.

469. **Kreatin**, $C_8H_9N_3O_4,2HO$.—May be extracted from the juice of flesh. Is a neutral body, in brilliant colourless crystals, readily soluble in boiling water, the solution having a bitter, somewhat acrid taste. By the action of acids it loses the elements of water, and becomes *Kreatinin*, $C_8H_7N_3O_2$, which pre-exists to a small extent in the juice of flesh. It is also in colourless crystals, of an alkaline reaction, which combine readily with acids to form distinct salts. It is freely soluble in cold water. *Inosic acid* exists also in the juice of flesh; it does not crystallise, and has been obtained as a white amorphous powder, to which the formula $HO,C_{10}H_6N_2O_{10}$ has been given. *Inosite*, $C_{12}H_{12}O_{12}+2HO$, is a sweet crystalline body, capable of undergoing the lactic, but not the vinous fermentation; it is obtained from the juice of the flesh of the heart and kidneys, also from unripe kidney-beans.

470. **Blood.**

Prop.—When freshly drawn, is a homogeneous, slightly viscid, alkaline liquid, of a peculiar odour, and saltish taste; its average s. g. is 1055; the colour varies from the bright red of arterial to the dark purple of venous blood. Under the microscope, is seen to consist of a transparent, nearly colourless fluid (*plasma* or *liquor sanguinis*), in which float red discs, the *red corpuscles*, and colourless globules, the *white corpuscles*. It soon coagulates after being drawn, forming a *clot*, which consists of fibrin and blood-globules, and a liquid *serum* containing albumen and salts. It consists proximately of

Water, . . .	784·
Red Corpuscles, . .	131·
Albumen, . . .	70·
Salts, ...	6·03
Extractive, Fatty Matters, etc.,	6·77
Fibrin, . . .	2·2
	1000·00

The red corpuscles consist of *Globulin*, a substance which has not been satisfactorily separated, but resembling albumen, and of *Hæmatin*, the red colouring matter. This contains a large proportion of iron. Mulder's analysis gives

Carbon, . . .	65·84
Hydrogen, . . .	5·37
Nitrogen, . .	10·4
Oxygen, . . .	11·75
Iron, . . .	6·64
	100·00

The colour of hæmatin does not depend wholly upon its iron, as it is not lost upon the removal of that metal. The proportion of globulin to hæmatin is stated as 123·5 to 7·4.

The *Extractive* matters consist principally of *Kreatin* and *Kreatinin;* the fatty matters, of a peculiar fat *Sero-*

lin, *Cholesterin*, a fat found in the bile, *Cerebrin*, a fat found in the brain, with oleate and margarate of soda and other fats free and saponified.

The *Salts* are chlorides of sodium, potassium, tribasic phosphate of soda, carbonate and sulphate of soda, and phosphates of lime, magnesia, and iron. Urea, biliary colouring matter, sugar, salivary matter, oxygen, nitrogen, and carbonic acid, are also found in varying quantities.

471. Chyle and Lymph.

Differ from blood chiefly in the absence of the red corpuscles, and in containing a less proportion of fibrin. The chyle, as taken from the lacteals, contains a large proportion of fatty matter.

472. Saliva.

A transparent, watery fluid, of an alkaline reaction; s. g. 1·006 to 1·009. Contains, besides water, mucus, albumen, fatty matter, and the usual salts, a peculiar principle, *Ptyalin*, and sulphocyanide of potassium, KC_2NS_2. Saliva contains 12 per cent. of chloride of sodium, a larger proportion than any other animal fluid. The *Pancreatic Juice* resembles saliva in composition, but does not contain sulphocyanogen.

473. Milk.

Under the microscope, is seen to consist of a clear liquid, in which are suspended numerous globules; these consist of fat (butter), surrounded by an albuminous envelope, which may be broken by mechanical violence (churning), or dissolved by caustic potassa. Milk contains water, butter, casein, milk sugar, and the usual salts of animal secretions. It is at first alkaline, but becomes acid, owing to the formation of *lactic acid*.

474. **Gastric Juice.**—Contains free muriatic and lactic acids, and phosphate of lime, the chlorides of potassium, sodium, calcium, and magnesium, and a peculiar principle,

Pepsin. Pepsin possesses the property of digesting most alimentary substances, when kept at the temperature of the stomach, and in contact with a dilute solution of muriatic, lactic, or phosphoric acid. The substance sold as pepsin for use in dyspepsia consists of starch containing pepsin obtained from the stomach of the sheep, hog, or calf, or of the same in solution in diluted hydrochloric acid.

475. **Sweat.**—Under ordinary circumstances, the average quantity secreted is nearly two pounds avoirdupois daily; under the influence of active exercise, or high temperature, this quantity is greatly increased. Its reaction is acid; the odour varies with the individual, and differs in different parts of the body. It is due to volatile acids, as the acetic, lactic, butyric, capric, and caproic; caprylic acid probably exists in that of the negro. It contains also animal matters, which when retained in the clothing become offensive and breed typhus, etc. Its salts are chlorides of sodium and potassium, acetates, lactates, etc. of soda and potassa.

476. **Bile.**—Is a liquid of a dark, golden-brown colour in man, s. g. 1018, probably neutral in reaction; it bleaches test-paper; has a bitter taste, and on agitation with air gives a soap-like foam. It is extremely prone to decomposition, and cannot on this account be obtained fit for analysis from man. The following is the composition of ox-bile:

Water, HO,	880·
Glykocholate of Soda, $NaO,C_{52}H_{42}NO_{11}$,	90·
Taurocholate of Soda, $NaO,C_{52}H_{45}NS_2O_4$,	
Biliverdine,	13·42
Fats,	
Cholesterine, $C_{26}H_{22}O$,	
	983·42

	983·42
Chloride of Sodium, $NaCl$,	15·24
Phosphate of Soda, $3NaO,PO_5$,	
" " Potassa, $3KO,PO_5$,	
" " Lime, $3CaO,PO_5$,	
" " Magnesia, $3MgO,PO_5$,	
Carbonate of Soda, NaO,CO_2,	
" " Potassa, KO,CO_2,	
Mucus of gall bladder, ...	1·34
	1000·00

Glykocholic Acid.—A crystalline body, which, when boiled with dilute KO,HO, splits, with the assimilation of two eq. of water, into cholic acid, $HO,C_{48}H_{39}O_9$, and glycocoll, $C_4H_5NO_4$ (468).

Tauro-cholic Acid.—Crystallises with great difficulty, and it is doubtful whether it has been obtained pure. By boiling with dilute KO,HO, it splits into cholic acid and taurin, $C_4H_7NS_2O_6$. Both the glyco- and tauro-cholates of soda are precipitated by the subacetate of lead; the glyco-cholate is also precipitated by the neutral acetate.

Taurin.—Is found in the decomposed bile of the intestines, and in the muscles of the mollusca. It has been artificially formed by heating isæthionate of ammonia to 410°–428°, $NH_4O,C_4H_5O,2SO_3 = C_4H_7NS_2O_6 + 2HO$ (Strecker). It is in colourless, hexagonal prisms, with no odour, but little taste; is permanent in the air, and burns with the evolution of sulphurous acid.

Cholic Acid.—Has been obtained crystallised; it is to it that the characteristic reaction of bile with Pettenkoffer's test is due.

Cholidic Acid, $C_{48}H_{39}O_9$, and *Dyslisin*, $C_{48}H_{36}O_6$, are two resinous bodies obtained from glykocholic acid by boiling with strong hydrochloric acid. The so-called resin of bile, or *Bilin*, is an impure mixture of the glyco- and taurocholate of soda.

Biliverdine.—Is the colouring matter of bile; it contains nitrogen and iron, but no satisfactory analysis has been made. It exists in very small quantity.

Cholesterine, $C_{25}H_{22}O$.—A fat-like body, but not saponifiable; exists in very small quantity in bile, but is abundant in gall stones. It is also found in the fluid of hydrocele, and in encysted tumours, the spleen, and largely in the brain and nervous tissue. It is not found in the fæces. It is in thin, colourless, transparent, rhomboidal plates, insoluble in water, but freely so in alcohol and ether.

Tests for Bile.—Nitric acid produces with Biliverdine a grass-green colour. This does not necessarily indicate the presence of bile proper. *Pettenkoffer's test:* This depends upon the reaction of sulphuric acid and grape sugar upon cholic acid. A drop of a solution of one part of sugar (cane sugar will answer) in 4 parts of water is added to the bile in watery solution; to this five drops of sulphuric acid are added, and the whole *gently* warmed (not above 120°). A red colour changing to purple is produced, which is destroyed by adding excess of water.

477. Urine.

Prop.—A clear liquid, of an amber colour and faint aromatic odour. Its mean s. g. is 1024, but varies with the ingesta from 1017 to 1030, the difference being due to the quantity of fluid, that of the solid constituents remaining nearly constant. Hence the specific gravity is inversely as the quantity which averages f℥xxiv *per diem*. If either the quantity or s. g. vary directly, it is an evidence of disease. It may be nearly colourless, as in hysteria, where the s. g. sometimes falls to 1006 with large increase of quantity, or may be of a deep red colour, and so scanty as to deposit its salts. In health, it has nearly always an acid reaction due to the acid phosphate of soda, $NaO,2HO,PO_5$, contained in it. It is most acid early in the morning, and has then a high s. g.; in the forenoon is pale, more abundant, of lower s. g., neutral, and even alkaline (Dalton). After this the colour, acidity, and density increase to a maximum towards night. These changes are liable to variations due to ingesta, temperature, etc. The alkalies, their carbonates, acetates, tartrates, and citrates, give to it an alkaline reaction. Although transparent when first passed, it may become turbid on cooling, from the deposition of mucus and salts; it readily putrefies, exhaling a peculiar offensive ammoniacal odour. This change is said to be due to the presence of a peculiar albuminoid ferment, *Nefrozyomase* (Béchamp). It may be prevented by filtering, or by the use of a drop of crude phenic acid to the pint of urine. The alkalinity of urine in cases of retention or of chronic vesical disease is due to this cause, and must be distinguished from that produced by ingesta, which give to the *secreted* urine an alkaline reaction.

The following analysis gives the average composition of human urine:

Water,	938·00
Urea, $C_2H_4N_2O_2$,	30·00
Kreatine,	1.25
Kreatinine,	1·50
Urate of Potassa, $2KO,C_{10}H_2N_4O_4$,	1·80
" " Soda,	
" " Ammonia,	
Colouring Matter and Mucus,	·30
Acid Phosphate of Soda, $NaO,2HO,PO_5$,	12·45
Rhombic " " " $2NaO,HO,PO_5$,	
" Phosphate of Potassa, $2KO,HO,PO_5$,	
" " " Magnesia, $3MgO,PO_5$,	
" " " Lime, $3CaO,PO_5$,	
	985·30

	985·30
Chlorides of sodium and potassium, . . .	7·80
Sulphates of soda and potassa, ...	6·90
	1000·00

478. **Urea**, $C_2H_4N_2O_2$.—Constitutes nearly one-half of the solid constituents of the urine. About 400 grains are discharged daily; the amount varies with the size, habits, etc. of the individual, but is greater after the use of animal food. It may be obtained by concentrating the fluid to a syrupy consistence and adding nitric acid. The resulting nitrate which deposits in crystals is decomposed by carbonate of lead, the urea dissolved out by alcohol, and crystallised.

Prop.—Is in colourless, neutral prisms resembling nitre in appearance; quite permanent and soluble in their own weight of cold water and in 4·5 parts cold and 2 of boiling alcohol; are insoluble in ether. Although neutral in composition, it forms salts with the acids. Heated with alkalies, it evolves ammonia. In contact with a ferment, it breaks up into carbonate of ammonia, $C_2H_4N_2O_2+3HO=2(NH_4O,CO_2)$; the same effect is produced by long boiling. It has been artificially formed, being identical (or isomeric) with cyanate of ammonia, NH_4O,CyO. It is always present in the blood, but in small quantity, being constantly eliminated by the skin and kidneys. If retained in the blood, as in albuminuria, it causes coma and other symptoms—*Uræmia*. It has been proposed to administer urea as a diuretic.

Kreatin and *Kreatine* have been described (469).

Urates.

Of these the urate of soda, $2NaO,C_{10}H_2N_4O_4$, is by far the most abundant; the average amount discharged daily being 25 grains. It forms the great part of the *Chalk stones* seen in the joints of gouty people. It is sparingly soluble in cold water, more so in boiling water, which deposits it again upon cooling. It dissolves readily in alkaline solutions; acids set free uric acid. The urates of potassa and ammonia resemble the former. The acid urate of ammonia, $NH_4O,HO,(C_{10}H_2N_4O_4)$, forms the bulk of the red deposits of the urine and of certain calculi.

479. **Uric Acid**, $2HO,C_{10}H_2N_4O_4$. — Exists, if at all, in very small quantity in healthy urine. It may be abundantly obtained from the excrement of birds (guano) and serpents, by boiling with caustic potassa, and neutralising the resultant urate of potassa with HCl.

Prop. — A soft, white, inodorous, insipid, crystalline powder, of a slightly acid reaction. Is soluble in 10,000 parts of cold and 1800 of boiling water; insoluble in alcohol and ether. By the cautious addition of nitric acid, and afterwards of ammonia, *Murexide*, $C_{12}H_6N_5O_8$, is obtained; it is of a beautiful purple, and when in mass, the crystals reflect light of a metallic-green colour, like the wing-cases of certain insects. It has been used as a dye, but is now generally replaced by the aniline purple.

480. **Hippuric Acid**, $HO,C_{18}H_8NO_5$. — Exists largely in the urine of the Herbivora; also in human urine, when Benzoic acid has been taken, or under vegetable diet.

Prop. — It crystallises in long, slender, milk-white prisms, of a bitter taste and acid reaction; soluble in 400 parts cold water and in boiling alcohol. Forms *Hippurates.* By boiling Hydrochloric acid is converted into Benzoic acid and Glycocoll (468). When urine containing Hippuric acid is allowed to putrefy, Benzoic acid is formed. That of commerce is sometimes thus obtained.

The *colouring matter* of urine has been variously termed, Urochrome, Uroxanthine, Urohæmatine, Urohodine, Uroglaucine, Uropittin, Uromelanine, etc. But little is known of its true character, and the statements of experimenters are very discordant. The odorous principle appears to consist of a resinous matter and a volatile oil. It is sometimes absent in the beginning of Bright's disease.

481. The *Phosphates* of the urine are tribasic. The acid Phosphate of soda, $NaO,2HO,PO_5$, is probably formed by the action of uric acid upon the rhombic phosphate, $2NaO,HO,PO_5$. The phosphates of lime and magnesia are held in solution by the acid phosphate, and to a small extent by chloride of sodium. When the urine becomes alkaline, they are deposited.

482. TESTS.

For Sugar.—1. Trommer's. Add a few drops of a solution of sulphate of copper, then an excess of caustic potassa; hydrate of the protoxide of copper, CuO,HO, will be precipitated. On boiling the mixture, this is instantly reduced to red suboxide of copper, Cu_2O, if grape-sugar be present; otherwise, to black CuO. Prolonged boiling should be avoided, as other organic matters present may then reduce the oxide of copper. Certain organic matters interfere with this reaction; they are removed by mixing the urine with pure animal charcoal and filtering (Dalton). 2. *Fermentation.*—A small portion of yeast added to diabetic urine will cause vinous fermentation. The evolved CO_2 may be collected and examined. Various other tests have been proposed, but the above are sufficient.

For Albumen.—Nitric acid coagulates it, rendering the liquid turbid or opaque; the same effect is produced by a heat of 170° or more. Both tests should be applied, and when taken together are conclusive.

Bile is detected, after concentration, by Pettenkoffer's test; its colouring matter by nitric acid; pus, spermatozoa, blood, etc., by the microscope.

483. **Urinary Deposits and Calculi.**

Lithic or Uric Acid.—The sediment is reddish; the urine strongly acid. The powder, heated on platinum foil or mica, or before the blowpipe on charcoal, burns, leaving no ash; it is insoluble in water, soluble in caustic potassa without evolution of ammonia, and, on the addition of nitric acid, is precipitated in white crystals. By the cautious addition of nitric acid, and, when cold, of ammonia, the characteristic purple of murexide is developed. The uric acid calculi are the most common.

Urate of Ammonia. — When heated, behaves as uric acid; when dissolved by caustic potassa, evolves ammonia, and then reacts as uric acid. It is soluble in boiling water, and precipitates again slowly on cooling. Calculi of this form are rare.

Phosphate of Lime. — The calculi are white, smooth, polished, and readily separate into layers. They are infusible before the blowpipe, and dissolve in dilute nitric acid. On the addition of ammonia, a gelatinous precipitate, $3CaO,PO_5$, is formed, which may be redissolved in acetic acid. To this add a drop of ferric chloride, a greenish-white precipitate of ferric phosphate will be formed; or add oxalate of ammonia, when a white precipitate of oxalate of lime will fall.

Phosphate of Magnesia and Ammonia, Triple Phosphate, MgO,NH_4O,HO,PO_5. — Calculi of this composition are rare, but often the salt is found alternating with others. The urine during its deposit is alkaline, and often offensive; an iridescent pellicle is seen on its surface. The calculi are usually colourless, and often rough and crystalline on the surface. Before the blowpipe it chars, exhales ammonia, swells, and ultimately fuses. Heated with caustic potassa, ammonia is evolved and magnesia precipitated; the latter may be redissolved by acid and tested with phosphate of soda and ammonia.

Fusible Calculus, is a mixture of the last-named with phosphate of lime, $3CaO,PO_5$. It is, next to uric acid, the most common. The urine is neutral or alkaline during its formation. The calculi are white, soft, and friable, resembling chalk. It *readily* fuses before the blowpipe, leaving a mixture of the tribasic phosphates of lime and magnesia. The latter may be detected by the methods mentioned above, and the presence of lime by the addition of oxalate of ammonia to the solution in acetic acid.

Oxalate of Lime. Mulberry Calculus.—Oxalate-of-lime deposits are frequent. They are seen under the microscope in octohedral crystals, and more rarely in the dumb-bell form. The calculi are usually rough and of a blood-stained appearance; sometimes they are small and smooth, forming the *hemp-seed* calculus. Before the blowpipe they burn away to carbonate, and ultimately to caustic lime. They are soluble without effervescence in dilute nitric and hydrochloric acids; the solution is precipitated white by ammonia. The residue, after exposure to the blowpipe flame, if not too hot, dissolves with effervescence in dilute hydrochloric acid, and is again precipitated by oxalate of ammonia.

Cystine ($C_6H_6NO_4S_2$) boiled with caustic potassa gives evidence of the presence of sulphur on testing with nitroprusside of sodium.

Xanthine, $C_{10}H_4N_4O_4$, dissolves in caustic potassa, and is reprecipitated by hydrochloric acid. When dissolved in nitric acid, it leaves a yellow residue on evaporation, which is not reddened by ammonia. The two last-named calculi are very rare.

APPENDIX.

I. WEIGHTS AND MEASURES.

Apothecaries' weight is used in compounding prescriptions. Its pound, ℔ = 12 troyounces, ℥ = 96 drachms, ʒ = 5,796 grains. The scruple, ℈j = 20 grains. Only the grain and troyounce are used in the U. S. P.; the latter contains 480 grains.

Troy weight agrees in the pound, ounce, and grain with apothecaries' weight, its pennyweight, dwt. = 24 grains.

Avoirdupois weight is the ordinary commercial weight. Its pound, ℔ = 16 oz. = 7000 grains. Its ounce contains 437·5 grains. The grains are equal in all these standards. In the British Pharmacopœia the avoirdupois pound and its subdivisions are used.

One ℔ Troy=0·822857 ℔ avoirdupois =13 oz., 72·5 grs.

One ℔ Avoirdupois=1·215227 ℔ troy=1 ℔, 2 ℥, 280 grs.

For Measures of Capacity, the *wine gallon* and its subdivisions are used in the U. S.; it contains 231 cubic inches. The British Pharmacopœia employs the Imperial gallon of 277,274 cubic inches. The minim, ♏, of the former weighs ·95 of a grain, of the latter ·91. The former contains 16 fluidounces to the pint, the latter 20. Only the minim, fluidrachm, fluidounce, and pint are used in the U. S. P.

Wine Measure, (U. S. P.)

60 minims = fʒj = ♏lx = 55·9 grs. water.
480 " = f℥j = fʒviii = 455·7 " "
7,680 " = Oj = f℥xvi = 7,291·2 " "
61,440 " = Congj = Oviii = 58,328·8 " "

Imperial Measure, (B. P.)

60 minims = fʒj = ♏lx = 54·6 grs. water.
480 " = f℥j = fʒviii = 437·5 " "
9,600 " = Oj = f℥xx = 8,750 " "
76,800 " = Congj = Oviii = 70,000 " "

THE DECIMAL SYSTEM,

Adopted in France and on the Continent, is used in this country in scientific research. The standard of length is the metre ($\frac{1}{10,000,000}$ of a quadrant of the earth's meridian), which is equal to 39·3685 inches, or, roughly, about 3¼ feet. This, as well as the measures of capacity and weight, is increased or divided decimally. The prefixes are *deca* (10 times), *hecto* (100 times), *kilo* (1000 times), and *myria* (10,000 times); *deci* ($\frac{1}{10}$), *centi* ($\frac{1}{100}$), *mille* ($\frac{1}{1000}$). The kilometre is equal to about two-thirds of a mile.

The cubic decimetre is the unit of a capacity, and is called a litre, and is equal to 1·765 imperial pints, or 2·1135 wine pints (the latter are used in the United States). The weight of 1 litre of water, at 39·10°, is called a kilogramme, and that of a millilitre of water a gramme=15·434 grains. The kilogramme is rather less than 2¼ lbs. avoirdupois. The metrical pound of France is half a kilogramme. One fluidounce equals in capacity 29·53 cubic centimetres.

Comparative Table of Decimal with Avoirdupois and Apothecaries' (U. S.) Weights.

Name.	Equivalent inGrammes.	Equivalent in Grains.	Equivalent in Avoirdupois.			Equivalent in Apothecaries' Weight, (U. S. P.)			
			lb.	oz.	gr.	lb.	oz.	dr.	grs.
Milligramme =	·001	·0154							
Centigramme =	·01	·1543							
Decigramme =	·1	1·5434							1·5
Gramme =	1·	15·4340							15·4
Decagramme =	10·	154·3402		0¼	·45			2	34·0
Hectogramme =	100·	1543·4023		3½	12·152		3	1	43·0
Kilogramme* =	1,000·	15434·0234	2	3¼	12·173	2	8	1	14·
Myriagramme =	10,000·	154340·2344	22	0¾	12·	26	9	4	20·

Comparison of Decimal Measures of Capacity with Wine (U. S. P.) and Imperial Measures.

Wine Measure.

	Eng. Cubic Inches.	Apothecaries' or Wine Measure.
Millilitre =	·061028 =	16·2318 minims.
Centilitre =	·610280 =	2·7053 fluidrachms.
Decilitre =	6·102800 =	3·3816 fluidounces.
Litre =	61·028000 =	2·1135 pints.
Decalitre =	610·280000 =	2·6419 gallons.
Hectolitre =	6102·800000	
Kilolitre =	61028·000000	

Imperial Measure.

1 litre = 0·22017 galls., 0·88066 qts., 1·76133 pts.
Stere (cubic metre) = 220·16643 galls.

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* Abbreviated, *kilo.*

II. OF INCOMPATIBLES.

SUBSTANCES which, when mixed, combine or mutually decompose, are said to be chemically incompatible.

It by no means follows that the new bodies formed are inert, and often two substances which are incompatible are mixed with the object of extemporaneously forming a third, as HgCl and KI. At other times, poisonous compounds are formed by mixing those which are comparatively inert, as Hg_2Cl and CaO,HO, or Hg_2I and KI.

The following general rules will be of use to the beginner in prescribing.

(1) Neutral salts containing the same base or the same acid do not decompose each other. Thus we may mingle the iodide and bromides of potassium, or these with the chlorate of potassa; or we may prescribe tartar emetic with tartrate of potassa and soda.

(2) Substances are incompatible with their tests and antidotes, as the very action of these depends upon chemical change. Thus, baryta and lead compounds with the soluble sulphates, tartar emetic with the vegetable astringents.

(3) The free acids generally unite with the oxides and decompose the carbonates; the same is true of salts having an acid reaction.

(4) The alkalies and alkaline earths and their carbonates generally precipitate the salts of the heavy metals (243).

(5) The vegetable astringents precipitate most of the salts of the heavy metals, the alkaloids and alumina. Hence, vegetable and mineral astringents are chemically incompatible.

(6) The iodides and bromides precipitate most of the salts of the heavy metals; the chlorides, the lead, mercury, and silver salts only.

The following preparations should either be given alone, or, if combined, it should be with caution, as they are readily decomposed: Lugol's, Donovan's, and Fowler's solutions; lime-water, solution of potassa, hydrocyanic and nitro-muriatic acids, tartar emetic, cyanide of potassium, acetate of zinc, nitrate of silver.

III. ANTIDOTES OF THE MORE COMMON POISONS.

NOTE.—In all cases, the poison or its compound with the antidote should be as speedily as possible removed from the stomach, and its constitutional and local effects combated by general measures.

Strong Acids. Alkaline carbonates, chalk, magnesia, soap, etc.

Oxalic and Tartaric Acid and their soluble salts. Chalk, whitewash.

Alkalies, caustic and carbonated. Weak acids (vinegar, lemon-juice), fixed oils.

Baryta, Lime, and Lead Salts. The soluble sulphates (Epsom or Glauber's salt).

Alum. Alkaline carbonates.

Tin Salts. Magnesia, carbonate of soda, milk.

Zinc and Iron Salts. The alkaline carbonates, the vegetable astringents.

Copper and Mercury Salts. Creasote; albumen, milk.

Nitrate of Silver. Common salt.

Tartar Emetic. The vegetable astringents; green tea.

Chloride of Antimony. Magnesia, carbonate of soda.

Arsenious Acid. Ferric hydrate; magnesia.

Fowler's Solution. Ferric salts.

Iodine. Boiled starch.

Phosphorus. Magnesia (?).

Hydrocyanic Acid. Ammonia; chlorine by the mouth and inhaled (cautiously); ferric salts, followed by alkaline carbonates; cold douche to the spine.

Hepar Sulphuris. Sulphate of zinc.

The Alkaloids, Poisonous Mushrooms, and the organic poisons generally. Tannic acid; animal charcoal.

Stings of Insects. Ammonia, locally.

Bites of Serpents, etc. Bibron's Antidote (367); whiskey in large doses; cauterisation of the wound; a cupping-glass or suction of the wound; a ligature between the wound and the trunk.

Bites of Rabid Animals, dissecting wounds, *pustula maligna.* No known antidote. Use the general measures indicated in the last paragraph.

Precautions in Medico-Legal Examinations for Poisons.

(1) The viscera to be examined should immediately upon their removal be put into clean glass vessels—new, if possible—and sealed; the seal is to remain unbroken until the vessel is opened in the laboratory.

(2) All the tests, vessels, and implements employed in the investigation must be absolutely pure and clean. The glass and porcelain ware should be new.

(3) No one should have access to the laboratory in the absence of the investigator.

(4) The preliminary operation of dialysis should always be employed; previously soaking the viscera, cut fine, for 48 hours in distilled water at 90°. The dialyser may be 8 inches in diameter, and the liquid should not be more than one-half inch deep in it; the quantity of distilled water in the outer vessel should be four times that in the dialyser; the operation may be continued for forty-eight hours. This gives us the crystalline poison nearly free from organic matter.

(5) The suspected substance should be divided into several equal portions, and *never* all employed in a single trial.

(6) It is important to detect, if possible, the poison as it was administered; thus AsO_3, not merely the presence of As.

(7) The tests should be so employed that, if more than one poison be present, all may be detected.

(8) When the poison has been administered some time before death, it may not be found in the stomach, and the other viscera must be examined. Vomited matters, etc. should always be examined, if they can be procured.

IV. REACTIONS FOR PRACTICE.

WHEN the student is unable to work out the right-hand number of the following equations, he will find it by referring to the paragraph indicated.

To make O (181):
KO,ClO_5 (heated) $=$
To make H (186):
$Zn + HO,SO_3 =$ *
$Zn + HCl =$
To make NO (204):
NH_4O,NO_5 (heated) $=$
To make NO_2 (203):
$Cu_3 + 4(HO,NO_5) =$ †
To make HO,NO_5 (201):
$KO,NO_5 + 2(HO,SO_3) =$

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* The excess of water present is not regarded (186).

† HO,NO_5 is too strong for use in practice; $4HO,NO_5$ is more accurate, but the excess of water is omitted for the sake of simplicity.

To make CO_2 (208):
$CaO,CO_2+HO,SO_3=$
$CaO,CO_2+HCl=$
To make HO,SO_2 (216):
$2(HO,SO_3)+C=$
$2(HO,SO_3)+Cu=$
$2(HO,SO_3)+S=$
To make HO,SO_3 (approximate), (216):
$2SO_2+NO_4=$
$2(FeO,SO_3)=$
To make HS (217):
$FeS+HO,SO_3=$
$SbS_3+3HCl=$ (364)
Hypophosphite (221):
$3(CaO,HO)+P_4=$
Phosphoric Acid (220):
$P_3+5(HO,NO_5)=$
The 3 varieties of PO_5 with AgO,NO_5 (220):
$AgO,NO_5+NaO,PO_5=$
$2(AgO,NO_5)+2NaO,PO_5=$
$3(AgO,NO_5)+2NaO,HO,PO_5=$
To make Cl (223):
$2HCl+MnO_2=$
To make HCl (228):
$NaCl+HO,SO_3=$
To make a Chlorate (226):
$6(KO,HO)+Cl_6=$
To make a Hypochlorite (227):
$2(CaO,HO)+Cl_2=$
Hydriodic Acid (233):
$I+HO+HS=$
Hydrofluoric Acid (234):
$CaF+HO,SO_3=$
Hydrocyanic Acid (236):
$AgCy+HCl=$

Caustic Potassa (248):

$KO,CO_2+CaO,HO=$

Iodide of Potassium (251):

$6(KO,HO)+I_6=$

Bromide of Potassium (252):

$FeBr+KO,CO_2=$

Acetate of Potassa (259):

$KO,CO_2+HO,C_4H_3O_3=$

Carbonate of Soda (approximate) (265):

$NaCl+HO,SO_3=$

$NaO,SO_3+C_4+CaO,CO_2=$

Labarraque's Solution (269):

$CaO,ClO+CaCl+2(NaO,CO_2)=$

Rochelle Salt (260):

$KO,HO,C_8H_4O_{10}+NaO,CO_2=$

Ammonia:

$NH_4O,SO_3+CaO,HO=$

Sesquicarbonate of Ammonia (278):

$3NH_4Cl+3(CaO,CO_2)=$

Precipitated Carbonate of Lime (288):

$CaCl+NaO,CO_2=$

Chloride of Calcium (287):

$CaO,CO_2+HCl=$

Hydrated Sesquioxide of Iron (314):

$Fe_2O_3,3SO_3+3(NH_4O,HO)=$

Ferric Chloride (316):

$Fe_6+9HCl+HO,NO_5=$

Ferrous Sulphate (321):

$Fe+HO,SO_3=$

Ferric Sulphate (321):

$6(FeO,SO_3)+HO,NO_5+3(HO,SO_3)=$

Ferric Nitrate (319):

$Fe_2+4(HO,NO_5)=$

Ferrous Carbonate (320):

$FeO,SO_3+NaO,CO_2=$

Ferric Pyrophosphate (322):
$3(2NaO,PO_5)+3(Fe_2O_3,3SO_3)$
Subnitrate of Bismuth (343):
$Bi+4(HO,NO_5)=$
$4(BiO_3,3NO_5)+nHO=$
Oxides of Mercury (363):
$Hg_2Cl+KO,HO=$
$HgCl+KO,HO=$
Chlorides of Mercury (366):
$HgO,SO_3+NaCl=$
$Hg_2O,SO_3+NaCl=$
Sulphate of Mercury (371):
$Hg+2(HO,SO_3)=$
Nitrate of Silver (375):
$Ag_3+4(HO,NO_5)=$
Nitro-benzole into Aniline (417):
$C_{12}H_5NO_4+H_6=$

V. LIST OF MINERALS WITH THEIR CHEMICAL COMPOSITION.

SELECTED FROM DANA'S MINERALOGY.

NOTE.—The name of a mineral is often applied to bodies of different but isomorphous composition. When this is the case, the replacing bases are written together in a parenthesis, or one above the other, and the formula is necessarily more or less indefinite.

Sassolin, BO_3+3HO.
Heavy Spar, BaO,SO_3
Celestine, SrO,SO_3.
Witherite, BaO,CO_2.

Strontianite, SrO,CO_2.
Periclase, MgO.
Brucite, MgO,HO.
Gypsum (alabaster), CaO,SO_3+2HO.
Anhydrite, CaO,SO_3
Calcite (calc-spar, satin-spar, dog-tooth spar), CaO,CO_2.
Dolomite, $CaO,CO_2+MgO,(FeO)CO_2$.
Apatite, $3(3CaO,PO_5)+Ca(Cl,F)$.

Sapphire, Corundum, Emery, Al_2O_3.
Diaspore, Al_2O_3,HO.
Gibbsite, $Al_2O_3,3HO$.
Alunogen, $Al_2O_3,3SO_3+18HO$.
Turquoise, $2(Al_2O_3),PO_5+5HO$.
Cryolite, $3NaF,2Al_2F_3$.

Quartz (chalcedony, carnelian, onyx, sardonyx, heliotrope, amethyst), SiO_3.
Opal, SiO_3+xHO.
Okenite, $3CaO,4SiO_3+6HO$.
Datholite, $3CaO,4SiO_3+3(CaO,BO_3)+3HO$.

Talc, $4MgO,SiO_3$.
Meerschaum, MgO,SiO_3+HO.
Serpentine, $9MgO,4SiO_3+6HO$.

Wollastonite, $3CaO,2SiO_3$.
Edelforsite, CaO,SiO_3.
Pyroxene, $3(CaO,MgO,FeO,MnO,ZnO)2SiO_3$.
Hornblende, $4(CaO,MgO,FeO,MnO,ZnO,)3SiO_3$.
Kaolin, Al_2O_3,SiO_3+2HO

Zeolites.

Heulandite, $3(CaO,SiO_3)+4(Al_2O_3,2SiO_3)+18HO$.
Stilbite, $CaO,SiO_3+Al_2O_3,3SiO_3+6HO$.

Mesotype, $(NaO,CaO,)SiO_3+Al_2O_3,SiO_3+2HO$.
Kyanite, $3Al_2O_3,2SiO_3$.
Andalusite, $3Al_2O_3,2SiO_3$.
Staurotide, $2(Al_2O_3,Fe_2O_3)SiO_3$.

Feldspar Family.

Orthoclase, $KO,SiO_3+Al_2O_3,SiO_3$.
Albite, $NaO,SiO_3+Al_2O_3,SiO_3$.
Oligoclase, $(CaO,NaO)SiO_3+Al_2O_3,2SiO_3$.
Labradorite, $(CaO,NaO)SiO_3+Al_2O_3,SiO_3$.
Petalite, $3(LiO,NaO)4SiO_3+4(Al_2O_3,4SiO_3)$.
Spodumene, $3(LiO,NaO)4SiO_3+4(Al_2O_3,2SiO_3)$.

Garnet, $$3\left\{\begin{matrix}CaO\\FeO\\MnO\end{matrix}\right\}SiO_3+\left\{\begin{matrix}Al_2O_3\\Fe_2O_3\end{matrix}\right\}SiO_3.$$
Epidote, $3CaO,SiO_3+2(Al_2O_3,Fe_2O_3,SiO_3)$.
Mica, $KO,SiO_3+4(Al_2O_3,Fe_2O_3)SiO_3$.
Topaz, $2(Al_2F_3)+5(Al_2O_3,SiO_3)$.
Sodalite, $3NaO,SiO_3+3(Al_2O_3,SiO_3)+NaCl$.
Spinel, $$\left\{\begin{matrix}MgO\\ZnO\\FeO,MgO\end{matrix}\right\}Al_2O_3.$$
Beryl, $3BeO,2SiO_3+Al_2O_3,2SiO_3$.
Chrysoberyl, BeO,Al_2O_3.
Zircon, Zr_2O_3,SiO_3.

The Heavy Metals.

Cassiterite, SnO_2.
Tin Pyrites, $2(Cu,Fe,Zn)S+SnS_2$.

$\left.\begin{array}{l}\text{Rutile,}\\ \text{Anatase,}\\ \text{Brookite,}\end{array}\right\} TiO_3.$
Molybdenite, MoS_2.

Sphene, $3CaO,2SiO_3+3TiO_3$.
Wolfram, $(FeO,MnO)WO_3$.
Pitchblende, UO,U_2O_3.
Uranochre, U_2O_3.

Uranite, $\left\{\begin{array}{l}CuO\\ CaO\end{array}\right\} PO_5+4U_2O_3,PO_5+16HO$.
Antimony Glance, SbS_3.
Arsenical Antimony, $SbAs_3$.
Realgar, AsS_2.
Orpiment, AsS_3.

Pyrites, FeS_2.
Marcasite, FeS_2.
Magnetic Pyrites, Fe_7S_8
Leucopyrrite, $FeAs$.
Mispickel, $FeAs,FeS_2$.

Specular Iron Fe_2O_3.
Magnetite, FeO,Fe_2O_3.
Franklinite, $(FeO,MnO,ZnO)(Fe_2O_3,Mn_2O_3)$.
Chromic Iron, $(FeO,MgO)Cr_2O_3$.
Brown Hematite, $Fe_2O_3,3HO$.
Lepidokrokite, Fe_2O_3,HO.

Spathic Iron, FeO,CO_2.
Vivianite, $3(FeO),PO_5+8HO$.
Scorodite, Fe_2O_3,AsO_5+4HO.

Manganblende, MnS.
Hauerite, MnS_2.

Pyrolusite, MnO_2.
Hausmannite, MnO,Mn_2O_3.
Braunite, Mn_2O_3.
Polianite, MnO_2.
Manganite, Mn_2O_3+HO.
Wad, $MnO \pm Mn_2O_3 \pm MnO_2$.

Rhodonite, $3MnO,2SiO_3$.

Millerite, NiS.
Syepoorite, CoS.
Copper Nickel, Ni_2As.
Smaltine, $CoAs$.
Cobaltine, CoS_2+CoAs.

Emerald Nickel, NiO,CO_2+6HO

Blende, ZnS.
Greenockite, CdS.
Red Zinc Ore, ZnO.
Electric Calamine, $3ZnO,SiO_3+1\frac{1}{2}HO$.
Willemite, $3ZnO,SiO_3$.
Smithsonite, ZnO,CO_2.

Galena, PbS.
Clausthallite, $PbSe$.
Plumbic Ochre, PbO.
Cerusite, PbO,CO_2.
Anglesite, PbO,SO_3.
Caledonite, $(PbO,CuO)(SO_3CO_2)$.
Pyromorphite, $3(3PbO,PO_5)+PbCl$
Crocoisite, PbO,CrO_3.

Copper Glance, CuS.
Covelline, CuS_2.
Erubescite, $(CuFe)S+3CuS+Fe_2S_3$.

Copper Pyrites, $CuS+Fe_2S_3$.

Domeykite, Cu_3As.
Algodonite, $Cu_{12}As$.
Whitneyite, $Cu_{18}As$.

Red Copper, Cu_2O.
Tenorite, CuO.
Atacamite, $CuCl+CuO,HO$.

Azurite, $2(CuO,CO_2)+CuO,HO$.
Malachite, CuO,CO_2+HO.

Cinnabar, HgS.
Calomel, Hg_2Cl.

Silver Glance, AgS.
Pyrargyrite, $3AgS,SbS_3$.
Proustite, $3AgS,AsS_3$.
Horn Silver, $AgCl$.

VI. GLOSSARY.

[Where no definition is given, it will be found by referring to the paragraph indicated.]

A

ACETONE. $C_6H_6O_2$ (406).
ACID. (149.)
ACROLEIN. $C_6H_4O_2$.
ACTINISM. The chemical effects of light.
ÆOLOPILE. An instrument for producing a blast by means of the vapour of a liquid heated in a close vessel.
ÆRUGO. Verdigris (330).

Æthiops. Black sulphide of mercury.

Aerometer. Hydrometer (16).

Alembic. A form of still, used also in sublimation.

Alkarsin. Oxide of kakodyl. C_4H_6AsO (426).

Allotropic. A modification of a body, in which its physical but not its chemical properties differ, as phosphorus and red phosphorus.

Alloy. Amalgam (242).

Amadou. Agaric, punk.

Amide. Amidogen, NH_2. Also used as an adjective.

Amidon. Starch.

Amorphous. Without crystalline form.

Amphigen, Amphide. (184.)

Analysis. (173.)

Anhydrous. Free from water.

Anode. The + pole of a voltaic circuit.

Apple Oil. Valerianate of amyl oxide (415).

Aqua Fontana. *Aqua*, U. S. P. (191).

Aqua Fortis. Crude nitric acid.

Aqua Phagedænica. Yellow wash (365).

Aqua Regia. Nitromuriatic acid.

Aqua Vitæ. Brandy.

Argentine Flowers of Antimony. (SbO_3.)

Argillaceous. Containing clay.

Argols. Crude cream of tartar.

Atom. The ultimate portion of an elementary body.

Atomic Number. The specific gravity of a substance divided by its equivalent.

Atomic Volume. The equivalent of a substance divided by its specific gravity.

Atomic Weight. Equivalent (148

Atomiser. An instrument for diffusing the spray of liquids (195).

Auripigmentum. Orpiment, AsS_3.

AUSTRAL. The southern polarity of a magnet.

AZOTE. Nitrogen.

AZOTIC ACID. Nitric acid.

B.

BALDWIN'S PHOSPHORUS. Fused CaO,NO_5.

BALSAM OF SULPHUR. A solution of S in *Ol. olivæ.*

BANANNA ESSENCE. (415.)

BARILLA. The ashes of sea-plants and of *Salsola Soda.*

BASACIGEN. Amphigen (184).

BASE. A substance capable of combining with acids to form salts.

BASIC. (1) A substance having the properties of a base. (2) A salt containing an excess of base.

BASYL. A term applied to the electro-positive group comprising hydrogen, the metals, and the *quasi* metals.

BATTERY. An apparatus for the accumulation of electricity.

BAUMÉ. The name of the inventor of a hydrometer; it is applied to distinguish the degrees, which are arbitrary.

BESTUCHUF'S TINCTURE. An ethereal solution of Fe_2Cl_3.

BIBRON'S ANTIDOTE. (367.)

BINARY. A compound of two elements, as HO.

BITTERN. The solution remaining after extracting $NaCl$ from sea-water.

BLACK ASH. Impure NaO,CO_2.

BLACK FLUX. Made by deflagrating cream of tartar with one-half its weight of nitre; contains carbon and KO,CO_2.

BLACK LEAD. Plumbago, a variety of carbon.

BLACK SALTS. The ley of wood-ashes evaporated nearly to dryness.

BLACK WASH. Contains suboxide of mercury, Hg_2O, (363).

Bleaching Powder. *Calx chlorinata* (291).
Blende. Native sulphide of zinc.
Blue Mass. *Pilulæ Hydrargyri* (364).
Blue Ointment. *Unguentum Hydrargyri* (364).
Blue Vitriol, or Bluestone. Sulphate of copper.
Bole. An argillaceous earth.
Bone Ash (218). Bone black (206).
Borax. Biborate of soda.
Boreal. The northern polarity of a magnet.
Brass. An alloy of copper and zinc.
Brimstone. Roll sulphur.
British Barilla. Black ash.
British Gum. Dextrin (387).
Bronze. An alloy of copper and tin.
Brunswick Green. Oxychloride of copper.
Burnett's Disinfecting Fluid. Contains ZnCl.
Butter of Zinc, Antimony, and Bismuth. Their chlorides.

C.

Cadet's Liquid. Alkarsin.
Calamine. Impure, native carbonate of zinc.
Calcareous Spar. Calcite, CaO,CO_2.
Calcedony. SiO_3.
Calcination. Exposure of substances to a high heat in an open vessel, so that the oxygen of the air may combine with their oxidisable constituents.
Calcined Mercury. HgO.
Calomel. Hg_2Cl (366).
Camphene. Oil of turpentine.
Canton's Phosphorus. CaS.
Caput Mortuum. The residue after sublimation.
Caramel. Burned sugar.
Carbolic Acid. Phenic acid.

Catalysis. The action of a body in promoting combination, or decomposition, by its presence, the body itself remaining unchanged.

Cathode. The negative pole of a voltaic circuit.

Chalk. An amorphous carbonate of lime, CaO,CO_2.

Chameleon Mineral. Manganate of potassa, KO,MnO_3.

Chemical Food. (330.)

Chloroid. The negative pole, or that connected with the zinc plate of a battery.

Choke Damp. Carbonic acid.

Chrome Green. A mixture of chrome yellow and prussian blue; or sesquioxide of chromium.

Chrome Vermilion. Dichromate of lead, $2PbO,CrO_3$.

Chrome Yellow. Chromate of lead, PbO,CrO_3.

Cinnabar. Native HgS.

Citrine Ointment. Ointment of the nitrate of mercury.

Clay. Impure silicate of alumina.

Clay Ironstone. Contains FeO,CO_2.

Cohobation. Returning the distillate to the retort, and repeating the operation.

Colcothar. Fe_2O_3.

Colloids. Jelly-like bodies. See **Dialysis** (128).

Colophony. Common resin, or rosin.

Combining Weight. Equivalent.

Condy's Solution. Contains permanganate of potassa. KO,Mn_2O_7.

Common Salt. $NaCl$.

Copperas. Green vitriol, FeO,SO_3+7HO.

Corrosive Sublimate. $HgCl$.

Cream of Tartar. Bitartrate of potassa, $KO,HO,\bar{T}$.

Crocus of Antimony, or Crocus Metallorum. Oxysulphide of antimony

Crocus Martis. Colcothar.

Crystals of Venus. $CuO,C_4H_3O_3+HO$.

Crystalloids. See **Dialysis** (128).

Cubic Nitre. NaO,NO_5.

Cupellation. See **Analysis** (173).

D.

Decantation, Decoction, and Displacement. (191.)

Decrepitation. The crackling of certain salts, when suddenly heated.

Deflagration. A rapid and scintillating combustion. It takes place in certain mixtures containing the nitrates, or chlorates.

Deliquescent. A term applied to those substances which attract moisture from the air, and liquefy.

Destructive Distillation. Dry distillation

Detonation. Rapid chemical action, accompanied by flame and noise.

De Valangin's Arsenical Solution. Contains AsO_3 in dilute HCl.

Dew-point. The temperature at which the moisture of the air begins to deposit.

Dialysis. (128.)

Diamagnetic. Repelled by both poles of a magnet.

Digestion and Displacement. (191.)

Dimorphous. Crystallising in two distinct systems.

Distillation. The process for separating a liquid from a solid or less volatile liquid, by heating the mixed substances, and collecting the condensed vapour.

Donovan's Solution. Contains the iodides of arsenic and mercury (367).

Dry Distillation. The process by which solid, or organic bodies, are subjected to heat in a close vessel.

Ductile. Capable of being drawn out into wire.

Dutch Gold. A species of brass.

DUTCH LIQUID. C_4H_4Cl.

" **WHITE.** Impure white lead.

E.

EAU DE JAVELLE. A solution of chlorinated potassa.

EBULLITION. The bubbling of a boiling liquid.

EDUCTS. The proximate principles of which bodies are supposed to be formed.

EFFERVESCENCE. The bubbling due to the escape of gas from a liquid.

EFFLORESCENCE. 1. A property peculiar to certain salts, which, exposed to the air, crumble, owing to the loss of a portion of their water of crystallisation. 2. The crust formed by the drying of certain salts upon the surface of bodies, in which they are not visible.

ELÆOPTANE. (448.)

ELAYLE. C_4H_4.

ELECTRODE. The pole of a voltaic circuit.

ELECTROLYSIS. Voltaic decomposition.

ELEMENT. A simple, undecomposable substance.

ELIXIR OF VITRIOL. Aromatic sulphuric acid.

ELUTRIATION. (191.)

EMERALD GREEN. Schweinfurth green (356).

EPSOM SALT. MgO,SO_3+7HO.

EQUIVALENT. The proportional numbers, according to which, or their multiples, bodies combine.

EREMACAUSIS. The slow decay of organic substances not containing nitrogen (380).

ESSENTIAL OILS. Volatile oils.

EUDIOMETER. An instrument for ascertaining the amount of oxygen in a gaseous body, by introducing an excess of hydrogen, exploding the mixture, and noting the diminution of volume.

EVAPORATION. Conversion into vapour, without ebullition.

F.

FERMENTATION. (396.)

FILTER. A porous substance used to separate a solid and liquid by allowing the latter to pass through, while the former is retained.

FIRE DAMP. Light carbonetted hydrogen (Marsh gas) mixed with air.

FIXED AIR. CO_2.

FLINT. SiO_3.

FLOWERS OF ANTIMONY. Oxide of antimony, SbO_3.

FLOWERS OF BENZOIN. Benzoic acid.

FLOWERS OF SULPHUR. *Sulphur sublimatum*, U. S. P.

FLOWERS OF ZINC. Oxide of zinc, ZnO.

FLUORESCENCE. The property possessed by certain bodies, as quinia salts, of rendering visible the dark chemical rays (156).

FLUOR SPAR. CaF.

FOLIATED EARTH OF TARTAR. $KO,C_4H_3O_3$.

FOWLER'S SOLUTION. Solution of the arsenite of potassa (356).

FRENCH CHALK. Silicate of magnesia.

FRUCTOSE. Fruit sugar (392).

FUMING LIQUOR OF LIBAVIUS. $SnCl_2$.

FUSEL OIL. Amylic alcohol, $C_{10}H_{12}O_2$.

FUSIBLE CALCULUS. (483.)

FUSIBLE METAL. (342.)

FUSION. The passage of a solid into the liquid state.

G.

GALENA. PbS.

GAS. An easily compressible elastic fluid.

GLASS. (304.)

Glass of Antimony. Roasted and fused tersulphide of antimony, SbS_3.

Glass of Borax. Fused borax, $NaO,2BO_3$.

Glauber's Salt. NaO,SO_3+10HO.

Glonöine. Nitro-glycerine (445).

Glucose. Grape sugar.

Glucoside. (395.)

Glycocoll. Sugar of gelatin.

Glycogene. Liver sugar.

Golden Sulphur. (365).

Goniometer. An instrument for measuring the angles of crystals.

Goulard's Extract and **Cerate.** Contain subacetate of lead.

Graphine. Carbon deposited in gas-retorts.

Graphite. Plumbago.

Green Vitriol. Copperas, FeO,SO_3+7HO.

Gypsum. CaO,SO_3+2HO.

H.

Halogen and **Haloid Salt.** (224.)

Harle's Solution. Contains arsenite of soda.

Hartshorn. Ammonia.

Hepar Sulphuris. Liver of sulphur (249).

Hoffmann's Anodyne. *Spirit Æther. Co.* (410).

Homberg's Pyrophyrus is made by heating potash alum and charcoal to ignition.

Homologous Bodies. (384.)

Hydracid. Hydrogen-acid. An acid consisting of a halogen united with hydrogen (224).

Hydrate. A combination of water.

Hydriodate. A salt of hydriodic acid. Is an incorrect term; *Iodide* of the metal should be used.

Hydrometer. (17.)

HYGROMETER. An instrument for the determination of the relative amount of moisture in the air.

I.

ICE VINEGAR. Glacial acetic acid, $HO,C_4H_3O_3$.

IMPONDERABLE. Without weight; sometimes employed to designate light, heat, electricity, and magnetism.

INCANDESCENCE. The glow of a highly-heated body.

INCINERATION. The reduction of a substance to ashes.

INCOMPATIBLE. Incapable of being mixed without chemical change.

INFUSION. (191.)

INOSITE. Sugar of flesh.

IODIC ÆTHER. Iodide of æthyl, C_4H_5I.

ION. A body going to the positive (anode) or negative (cathode) pole of a galvanic battery during electrolysis.

IRON PYRITES. Native sulphide of iron.

ISINGLASS. A variety of gelatin.

ISOMERIC. Substances having the same composition, with different properties. (384.)

ISOMORPHOUS. Substances having the same crystalline form. (245.)

IVORY BLACK. Animal charcoal made by distilling ivory scraps; is generally applied to bone black.

K.

KELP. Ashes of sea-weeds; used as a source of iodine and carbonate of soda.

KERMES' MINERAL. (365.)

KING'S YELLOW. Orpiment, AsS_3.

L.

LABARRAQUE'S DISINFECTING LIQUID. Solution of chlorinated soda.

LAC SULPHURIS. Precipitated sulphur.

LACTIN. Sugar of milk.

LAKE. A compound of alumina with an organic colouring matter.

LAMPBLACK. (206.)

LAPIS INFERNALIS. Lunar caustic, AgO,NO_5.

LAUGHING GAS. Nitrous oxide, NO.

LEAD WATER. Diluted Goulard's extract (350).

LEDOYEN'S DISINFECTING LIQUID. Solution of nitrate of lead.

LEVIGATION. The reduction of a substance to an impalpable powder, by rubbing on a moist slab with a flat pestle, called a muller.

LIMESTONE. A carbonate of lime, CaO,CO_2.

LIQUEFACTION. The conversion of a solid or a vapour into liquid.

LITHARGE. Semivitrified oxide of lead, PbO.

LITHIC ACID. Uric acid, $C_{10}H_4N_4O_6$.

LIVER OF SULPHUR. *Potass. sulphuret.* (249).

LIXIVIATION. The separation of the soluble portions of a substance by causing water to filter through it. (191.)

LOADSTONE. The native magnetic oxide of iron, Fe_3O_4.

LUGOL'S SOLUTION. Compound solution of iodine.

LUNAR CAUSTIC. Nitrate of silver.

LUTE. An adhesive mixture for closing the joints of apparatus, to prevent the escape of vapours, etc.

M.

MACERATION. The long-continued soaking of a substance in water at common temperatures

MACQUER'S SALT. $KO,2HO,AsO_5$.

MAGISTERY OF BISMUTH. Subnitrate.

MAGMA. A molasses-like mass.

MAGNESIA ALBA. *Magnesiæ carbonas.*

Malleable. Capable of being wrought under the hammer.

Marble. Crystallised carbonate of lime.

Marine Acid. Muriatic acid.

Martial Æthiops. F_3O_4.

Massicot. Protoxide of lead, PbO.

Matrass. A glass vessel, with a long neck, used for digestion.

Menstruum. A solvent.

Mercaptan. Alcohol in which the oxygen is replaced by sulphur, $C_4H_6S_2$.

Metalloid. A non-metallic body.

Metameric Bodies. Those having the same empirical with different rational formulæ (384).

Microcosmic Salt. NaO,NH_4O,HO,PO_5.

Milk of Sulphur. Precipitated sulphur.

Milk of Lime. Whitewash.

Mineral Water. Water charged with carbonic acid; also, natural waters holding medicinal substances in solution (50).

Mineral Yellow. Oxychloride of lead

Minium. Red oxide of lead, Pb_3O_4.

Molecule. The ultimate portion of a compound body.

Monsel's Salt. Subsulphate of iron.

Mountain Blue. Azurite.

Mountain Green. Malachite.

Mulberry Calculus. Oxalate of lime (483).

Muriate. The compound of muriatic acid with a base. Properly, the *chloride* of the metal, except in case of the alkaloids.

Muriated Tincture of Iron. *Tinct. Ferri Chlorid.*

Muriatic Acid. Hydrochloric HCl.

N.

Naphtha. A natural, oily carbohydrogen, $C_{14}H_{15}$.

Nascent. Being liberated from combination (143).

Natron. Native carbonate of soda.

Neutral. 1. Possessing neither acid nor alkaline reaction. 2. Having no tendency to combine with acids or bases. 3. Applied to salts, where the number of equivalents of the acid is equal to those of the oxygen in the base.

Neutral Mixture. Solution of citrate of potassa (261).

Nitre. Saltpetre, KO,NO_5.

Nitrile. A base derived from ammonia by the replacement of three equivalents of H (425).

O.

Obsidian. Volcanic glass.

Ochre. A native mixture of clay and sesquioxide of iron.

Oil of Vitriol. HO,SO_3.

Orpiment. AsS_3.

Osmose. The diffusion of liquids through porous septa (132).

Oxyacids. Oxygen acids; acids, the electro-negative constituent of which is oxygen.

Oxychloride. The combination of the chloride and oxide of a metal.

Oxysalt. The union of an oxygen acid with a base containing oxygen.

Oxysulphide. The combination of the oxide and sulphide of a metal.

P.

Packfong. A variety of German silver.

Particle. A minute portion of matter.

Pearl Ash. Impure carbonate of potassa.

Pearl Powder.	Subnitrate or oxychloride of bismuth.
Pearson's Salt.	$3NaO,AsO_5+24HO$.
Picric Acid.	Carbazotic acid (453).
Pinchbeck.	A species of brass.
Plaster of Paris.	Calcined sulphate of lime.
Platinum, Black and Sponge.	Finely divided platinum.
Plumbagine.	Carbon deposited in gas retorts.
Plumbago.	Native carbon.
Potash.	Impure carbonate of potassa.
Powder of Algaroth.	Oxychloride of antimony, $2SbO_3, SbCl_3,+HO$.
Precipitate.	The insoluble compound formed on mixing certain incompatible bodies.
Precipitatum per se.	HgO, made by direct oxidation.
Preston Salts.	Carbonate of ammonia with essential oils.
Prussic Acid.	Hydrocyanic acid, HCy.
Prussian Blue.	Ferrocyanide of iron, Fe_4Cfy_3.
Pseudomorph.	A mineral body crystallised in the form that belongs to another mineral.
Puceoxide of Lead.	PbO_2.
Purgative Mineral Water.	*Liq. Magnes. citrat.*
Putty Powder.	Stannic acid, SnO_2.
Pyrites.	Native sulphide of iron or copper.
Pyro.	A prefix to distinguish a body altered by heat from the one from which it is derived.
Pyroligneous Acid.	Impure acetic acid, obtained by the distillation of wood.
Pyrophorous.	A powder capable of igniting spontaneously in the air.
Pyroxilic Spirit.	Wood alcohol, $C_2H_4O_2$ (405).
Pyroxyline.	Gun-cotton (386).

Q.

Quaternary. A compound containing four elements.

Quevenne's Iron. *Ferrum redactum.*

Quicklime. Caustic lime, CaO.

Quicksilver. Mercury.

R.

Radical Vinegar. Glacial acetic acid, $HO,C_4H_3O_3$.

Reagent. An agent employed as a chemical test, or in chemical operations.

Realgar. Red sulphide of arsenic, AsS_2.

Red Precipitate. Red oxide of mercury, HgO.

Red Prussiate of Potash. Ferricyanide of potassium. K_3Cfdy.

Red Tartar. Argols.

Regulus of Antimony. Metallic antimony.

Rochelle Salt. Tartrate of potassa and soda, $KO,NaO,\bar{T}$.

Roche and **Roman Alums** are varieties of potash alum.

Rock Crystal. Quartz.

Roman Vitriol. Sulphate of copper, CuO,SO_3+6HO.

Rouge. Sesquioxide of iron; carthamine.

Rust. Oxide of iron; generally, hydrated sesquioxide.

S.

Saccharum Saturni. Acetate of lead, $PbO,C_4H_3O_3$.

Sal Acetosella. Binoxalate of potassa, $KO,2C_2O_3$.

Sal Aeratus. Bicarbonate of potassa, $KO,HO,2CO_2$.

Sal Alembroth. Double chloride of mercury and ammonium, $NH_4Cl,HgCl$.

Sal Ammoniac. Chloride of ammonium, NH_4Cl.

Sal Diureticus. Acetate of potassa, $KO,C_4H_3O_3$.

Sal Enixum. Bisulphate of potassa, $KO,HO,2SO_3$.

PEARL POWDER. Subnitrate or oxychloride of bismuth.

PEARSON'S SALT. $3NaO,AsO_5+24HO$.

PICRIC ACID. Carbazotic acid (453).

PINCHBECK. A species of brass.

PLASTER OF PARIS. Calcined sulphate of lime.

PLATINUM, BLACK and SPONGE. Finely divided platinum.

PLUMBAGINE. Carbon deposited in gas retorts.

PLUMBAGO. Native carbon.

POTASH. Impure carbonate of potassa.

POWDER OF ALGAROTH. Oxychloride of antimony, $2SbO_3, SbCl_3,+HO$.

PRECIPITATE. The insoluble compound formed on mixing certain incompatible bodies.

PRECIPITATUM PER SE. HgO, made by direct oxidation.

PRESTON SALTS. Carbonate of ammonia with essential oils.

PRUSSIC ACID. Hydrocyanic acid, HCy.

PRUSSIAN BLUE. Ferrocyanide of iron, Fe_4Cfy_3.

PSEUDOMORPH. A mineral body crystallised in the form that belongs to another mineral.

PUCEOXIDE OF LEAD. PbO_2.

PURGATIVE MINERAL WATER. *Liq. Magnes. citrat.*

PUTTY POWDER. Stannic acid, SnO_2.

PYRITES. Native sulphide of iron or copper.

PYRO. A prefix to distinguish a body altered by heat from the one from which it is derived.

PYROLIGNEOUS ACID. Impure acetic acid, obtained by the distillation of wood.

PYROPHOROUS. A powder capable of igniting spontaneously in the air.

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PYROXYLINE. Gun-cotton (386).

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Sal Ammoniac. Chloride of ammonium, NH_4Cl.

Sal Diureticus. Acetate of potassa, $KO,C_4H_3O_3$.

Sal Enixum. Bisulphate of potassa, $KO,HO,2SO_3$.

Thénard's Blue. A compound of alumina and oxide of cobalt.

Tincal. Native borax, $NaO,2BO_3$.

Tincture. A solution in alcohol. When in ether, is called an *Ethereal Tincture.*

Tombac and **Tutenag.** Species of brass.

Trituration. Rubbing in a mortar.

Trona. Native sesquicarbonate of soda, $2NaO,3CO_2$.

Turnbull's Blue. Ferricyanide of iron, Fe_3Cfdy.

Turner's Cerate. Calamine cerate.

Turner's Yellow. Oxychloride of lead, $PbCl+7PbO$.

Turpeth Mineral. Yellow sulphate of mercury, $3HgO,SO_3$.

Tutty. Impure oxide of zinc.

U.

Umber. A silicate of alumina, with oxides of iron, manganese, and water.

V.

Vallet's Mass. *Pil. Ferri carb.* contain FeO,CO_2.

Verd Antique. Precious serpentine.

Verdigris. Impure subacetate of copper.

Verditer, CuO,CO_2+HO,CO_2.

Vermilion. Artificial HgS.

W.

White Arsenic. Arsenious acid, AsO_3.

White Lead. Carbonate of lead.

White Precipitate. Chloramide of mercury, $HgCl,HgNH_2$.

White Vitriol. Sulphate of zinc, ZnO,SO_3+7HO.

WHITING. Prepared chalk, CaO,CO_2.

WOOD NAPHTHA and WOOD SPIRIT. Methyl alcohol, $C_2H_4O_2$.

WOOD VINEGAR. Pyroligneous acid. Impure acetic acid.

Y.

YELLOW PRUSSIATE OF POTASH. Ferrocyanide of potassium, K_2Cfy.

YELLOW WASH. Made by adding corrosive sublimate to lime water; hydrated protoxide of mercury is formed.

Z.

ZAFFRE. Impure oxide of cobalt.

ZINCOID. The positive pole of a battery; that connected with the copper or platinum plate.

ZINC WHITE. Oxide of zinc, ZnO.

ZYMOSIS. Decomposition by example (160, 396).

THE END

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